RAILWAY HANDBOOK 2016

ENERGY CONSUMPTION AND CO_2 EMISSIONS

FOCUS ON SUSTAINABILITY TARGETS

iea International Energy Agency

uic INTERNATIONAL UNION OF RAILWAYS

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.

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

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INTERNATIONAL UNION
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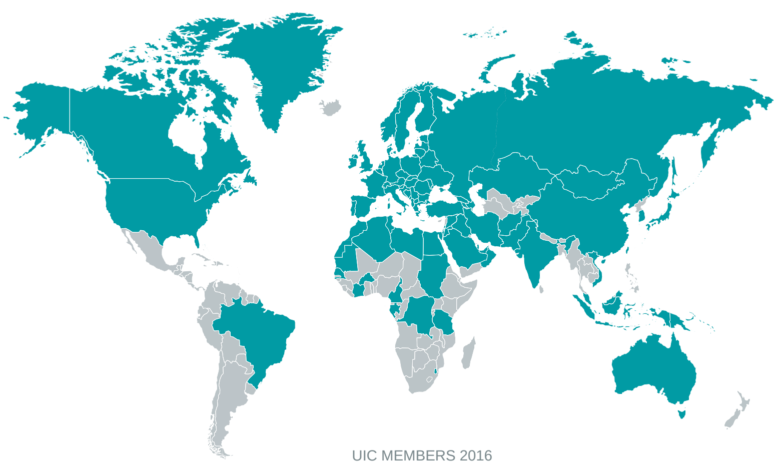
UIC: the international professional association representing the railway sector

UIC, the worldwide railway association, groups counts 200 members in 95 countries, including railway companies, infrastructure managers, rail transport operators and rail service providers. 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.

The UIC's main missions include understanding the business needs of the rail community, developing programmes of innovation to meet those needs and preparing and publishing professional railway standards that facilitate the implementation of the innovative solutions. The train and education of the people called upon to use these innovative solutions is vital and the organisation of training schemes is a core component in ensuring the competency of tomorrow's generation of rail personnel.

Representing rail with a wide range of international organisations such as the UN and cooperating with all organisations specialising in rail matters and transport issues right around the world is one of the prime raisons d'être of the UIC. UIC maintains and develop close cooperation links with all actors in the rail transport field, including manufacturers, railway associations, public authorities. The UIC Energy Environment & Sustainability (EES) Platform manages 5 expert networks (Energy & CO_2, Emissions, Sustainable Mobility, Noise and Sustainable Land Use) and a portfolio of projects focusing on the development of best practice, benchmarking for environmental sustainability and reporting of corporate and social responsibility. For info www.uic.org (http://www.uic.org).



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Foreword

The International Energy Agency (IEA) and the International Union of Railways (UIC) are pleased to jointly publish the fifth edition of the data handbook on "Energy Consumption and CO_2 Emissions" in the global railway sector. This publication marks the fifth year of cooperation between the two organizations and aims at providing insightful information, each year covering a special feature. In the past, these topics have ranged from the energy mix in the rail sector to the cost and sustainability impacts associated with rail infrastructure to vehicle efficiency. The success of past editions has encouraged us to continue this valuable joint effort.

This new edition takes into account the Paris Agreement, the historic outcome of the 21st UNFCC Conference of Parties in December 2015 in which more than 180 countries pledged to take steps to reduce greenhouse gas emissions. Part 2 of this year's handbook emphasizes the analysis and the evaluation of rail sector and national targets, also compared to other modes of transport. The results of our analysis indicate that historical evolution of specific energy consumption and specific CO_2 emissions from rail are on track to achieving the 2030 and 2050 UIC sustainability targets, moving the rail sector towards the 2 Degree Scenario (2DS) outlined in the IEA Energy Technology Perspectives publication.

One important finding is that rail transport offers a more sustainable alternative to most other transport modes, both in terms of energy use and carbon emissions per passenger-kilometre or tonne-kilometre, and is anticipated to continue to do so over the coming decades. Setting targets helps in understanding the scale of investments needed to support sustainable transport. Monitoring performances is also important to foster this shift, as it highlights the developments of the transport system and guides policy action aiming for its increased sustainability.

With each new edition, the rail and energy data continue to improve as a result of the close cooperation between the IEA and the UIC. For this 2016 Handbook, the main improvements result from the collection of more detailed and accurate energy data from UIC members and their commitment through the Climate Responsibility Pledge, and the latest IEA Energy Technology Perspectives data. In addition, the direct data collection from railways, which covers over 90% of the global rail transport activity, and the incorporation of this information into the IEA Mobility Model have increased the consistency of the data and provided a more solid background for the analysis presented in this handbook.

The IEA and UIC strongly believe in the capacity of the rail sector to monitor and improve energy consumption practices. We are hopeful that this assessment of the railway sector's performance will help to provide solid and consistent information to policy and decision makers, promoting the role of sustainable transport as one of the key actors towards a more energy efficient and low carbon future.

Fatih Birol

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, 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 Marine Gorner and Renske Schuitmaker under the supervision of Pierpaolo Cazzola, for the IEA, and by Gabriel Castañares Hernandez for UIC.

A special mention goes to the cooperation of Nicholas Craven, Cheul-Kyu Lee, Aurelia Kollros, Takumi Ishii and Zhangshan Zhao (UIC) for the completion of this work and to the contributions from UIC members improving the data collection.

Gratitude is also extended to the Sustainable Development Foundation for its technical support, especially to Raimondo Orsini, Massimo Ciuffini, Luca Refrigeri, Daniela Cancelli, Valeria Gentili, Camille Courouble and Ilaria Indri.

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Railway Handbook 2016

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Introduction

The production of the Railway Handbook 2016 has been an important opportunity to strengthen the collaboration between the IEA and the UIC. This relationship has served to enrich and improve the knowledge of activity, energy and emissions data associated with the railway sector. The previous editions of the Handbook are freely available from the UIC website.

The data provided within this handbook are derived from the synchrony of UIC rail infrastructure, activity, and energy use statistics (UIC 2015a; UIC 2015b) and IEA data on energy consumption and CO_2 emissions by end-use sector and fuel type (IEA 2015a; IEA, 2015b). For this year's edition, substantial improvements have been introduced regarding data collection from the main regions presented in the publication. Russia, Japan, USA, China, India and Korea have made particularly noteworthy strides to improve the caliber of data within the report.

As in previous editions, Part I of this year's Handbook is dedicated to presenting the most significant data and trends concerning energy consumption and CO_2 emissions from the rail sector, focusing on the most important Regions in terms of rail activity, namely EU 28, USA, Japan, Russia, India and China. This serves to place a spotlight on the regions and countries which cumulatively accounted for 89% of passenger-kilometres and 84% of tonne-kilometres travelled globally in 2013. In addition, statistics illuminating rail-related CO_2 emissions, passenger activities, freight activities, and electrification rates at a regional and global level are published within this section.

Furthermore, this Part pays particular attention to the growing role of high-speed trains in the rail sector, including but not limited to global coverage and the number of kilometres (in operation, construction, and planning phases). The sector of high-speed rail infrastructure was dominated by China in 2013, as it hosts 60% of the global High-Speed rail infrastructure, followed by Europe which accounts for a share of 24%.

In general, projections and trends regarding energy consumption, CO_2 emissions, and rail activity described in the previous editions are confirmed in this year's handbook. However, compared to the previous edition, the continuous improvement of calculation methods and analytical models produced minor changes in the world rankings with regards to the energy intensity and carbon intensity indicators. According to the Railway Handbook 2016 data, China has the lowest energy consumption per passenger-kilometre (40 kJ/pkm) and the lowest CO_2 emissions per passenger-kilometre (7 gCO_2/pkm), while Russia holds the lowest rate of energy consumption per tonne-km for goods transport by rail (86 kJ/tkm) and the lowest specific CO_2 emissions from freight (9 gCO_2/tkm).

In the context of the historic outcome of the 21st Conference of Parties in December last year, it was decided to dedicate Part II of the Railway Handbook 2016 to sustainability targets, framing an overview of the targets set by railway companies and countries alike. Part II also compares these targets with targets set for other modes of transport. The analysis confirms that the rail sector has continuously reduced its specific energy consumption and CO_2 emissions since 1990, and that this evolution is in line with the UIC Low Carbon Rail Transport Challenge targets for 2030 and 2050. Additionally, the analysis confirms that the rail sector offers the most efficient land-based mode of transport per passenger-kilometre and tonne-kilometre compared to other modes of transport.

At a global level, the UIC targets for reducing its specific energy use and CO_2 emissions has proven to be in line with the trajectory of the 2 Degree Scenario (2DS) outlined in the IEA Energy Technology Perspectives publication (IEA 2016a). Additionally, the UIC targets for the European rail sector are consistence with the trajectory set out in the IEA 2DS.

Part II also zooms in on commitments made by single countries to achieve the climate goals of the Paris Agreement. In this context, an analysis is included of the Intended Nationally Determined Contributions (INDCs) - representing the outlined actions individual countries intend to take under the Paris Agreement - aimed at understanding the extent to which single countries include the transport sector and the rail sector in their pledges.

Setting sustainability targets are paramount in the pursuit of minimizing the effects of climate change. Meaningful goals and analysis provide a mechanism by which to monitor progress. Concurrently, strong commitments serve as a foundation on which substantive and effective policy can be developed. Tenacious implementation of sustainability objectives and recurrent monitoring of sector performance are indispensable elements to realizing the goals set out by the international community.

Part I:
The Railway Sector
Main Data

World

Key Facts

- The transport sector was responsible for emitting 7.5 billion tCO_2 in 2013. The share of CO_2 emissions from transport has continuously increased since 2010, rising from 22.7% in 2010 to 23.4% in 2013. In 2013, 3.5% of transport CO_2 emissions were due to the rail sector, while railways transported 8% of the world's passengers and goods.

- The rail sector accounted for 2% of the total energy used in the transport sector, in 2013. The rail sector was for 57% fuelled by oil products and for 36.4% by electricity.

- In 2013, six regions and countries (EU 28, US, Russia, China, India, Japan) were responsible for 78% of overall CO_2 emissions of the rail sector, of which a quarter was emitted by China.

- Coal consumption in rail has dramatically fallen between 1990 and 2013. In the same period electricity use in rail has increased from 17.2% to 36.4%, including a significant rise in renewable electricity sources in the total energy mix of railways (from 3.4% to 8.7%).

- Global railway passenger activity grew by 133% between 1975 and 2013. China and India were the major contributors to this growth, with an eight-fold increase in railway activity, while EU28 activity grew by 10% in the same period. Freight activity has increased by 78% since 1975. USA, Russia and China are the top countries for freight transport on rail in terms of tonne-kilometers carried.

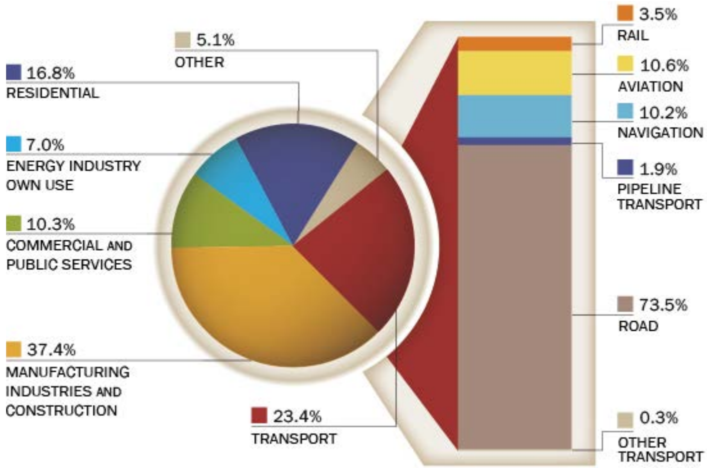
- The share of electrified railway tracks has increased by 163% between 1975 and 2013 at world level. China and Korea increased their share of respectively 325% and 343% from 1990 to 2013.

- The total length of high-speed lines in operation was more than 10 times higher in 2015 compared to 1990. China has taken the lead in high speed rail deployment and was hosting 60% of all high speed lines globally in 2015. Globally, high-speed passenger activity has almost doubled between 2000 and 2013.

- In 2013, the specific energy consumption of rail passenger transport was 138 kJ/pkm, while the specific energy consumption of rail freight transport was 129 kJ/tkm. Railways specific energy consumption decreased by 63% and 48% in passenger and freight services respectively, between 1975 and 2013.

- Specific CO_2 emissions in the rail sector have been following a similar improvement rate: they dropped by 60% in passenger services and by 38% in freight services between 1975 and 2013.

Fig. 1: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat production related emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

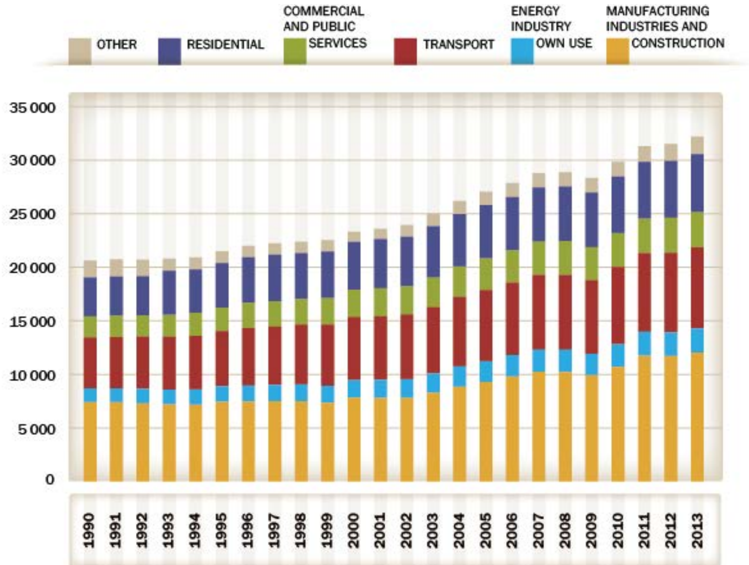
Source: Elaboration by Susdef based on IEA (2015a)

Table 1: **World transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	81.9%	8.3%	30.5%
AVIATION	11.4%	0.8%	4.0%
NAVIGATION	0.3%	82.2%	57.5%
RAIL	6.4%	8.7%	8.0%

Source: Elaboration by IEA based on IEA (2016b), UIC (2015a) and UNCTAD (2014)

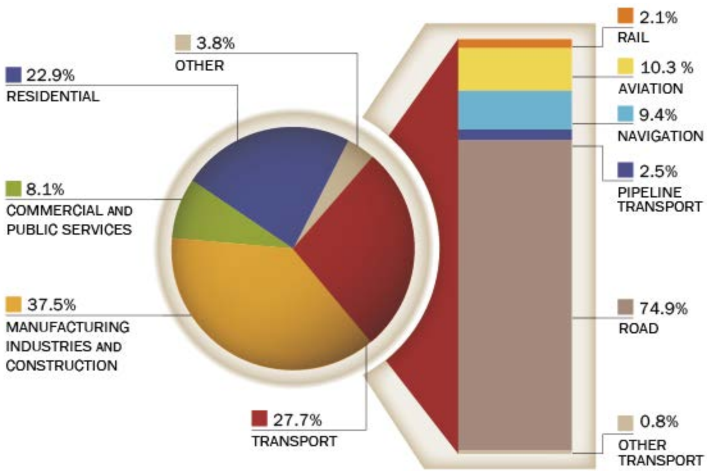
Fig. 2: **Total CO_2 emissions from fuel combustion by sector, 1990-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end use sectors.

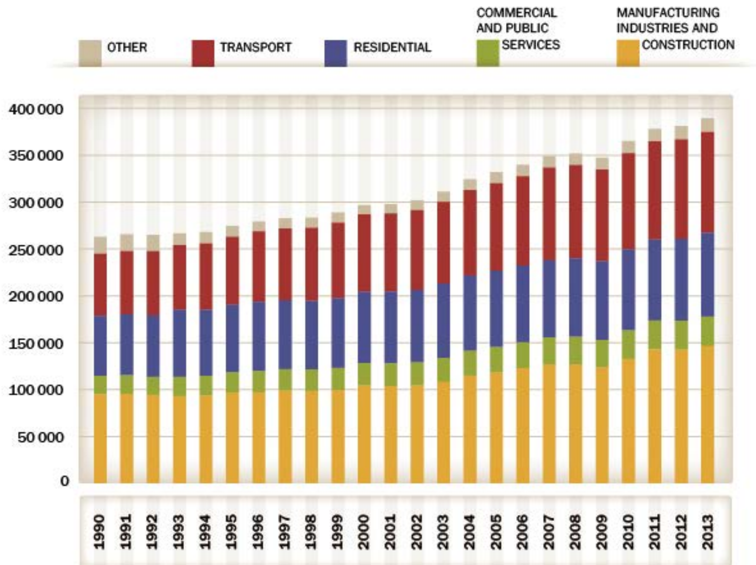
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 3: **Share of final energy consumption by sector, 2013**



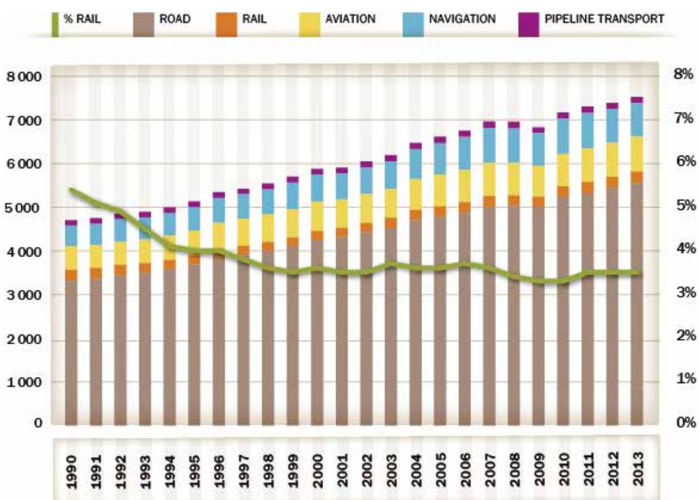
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 4: **Total final energy consumption by sector, 1990-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b)

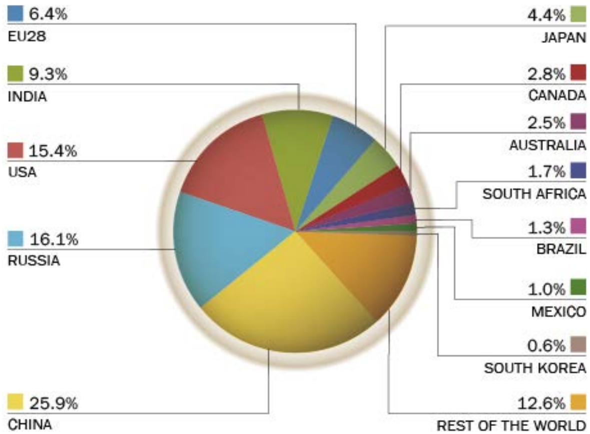
Fig. 5: **Transport sector CO_2 emissions by mode, 1990-2013 (million tCO_2 - left, share of rail in global CO_2 emissions - right)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.
In transport, all the emissions from electricity and heat production are reallocated to rail.

Source: Elaboration by Susdef based on IEA (2015a)

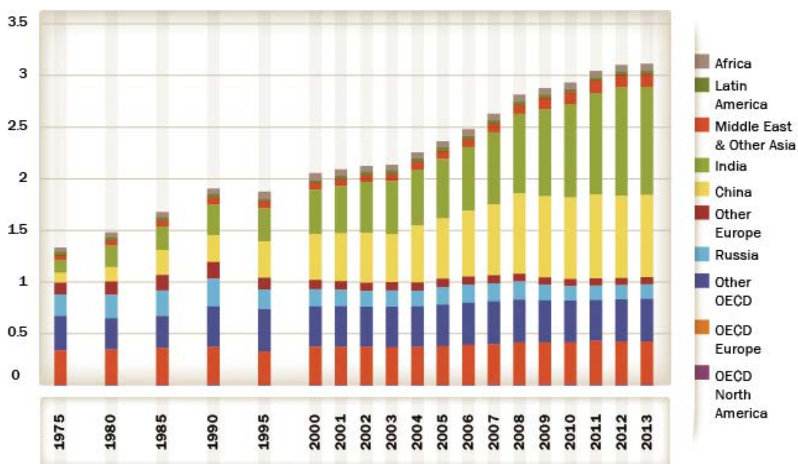
Fig. 6: **Share of railway CO_2 emissions by geographic area, 2013**



Note: All the emissions from electricity and heat production in transport have been reallocated to rail.

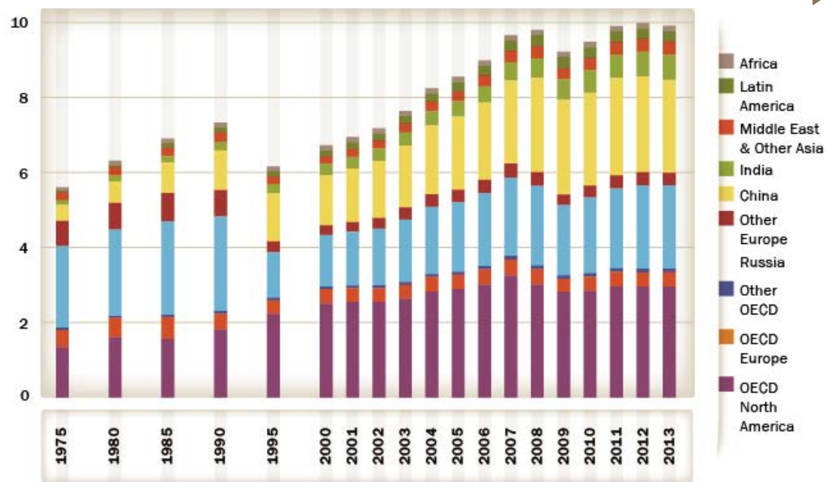
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 7: **Railway passenger transport activity by geographic area, 1975-2013 (trillion pkm)**



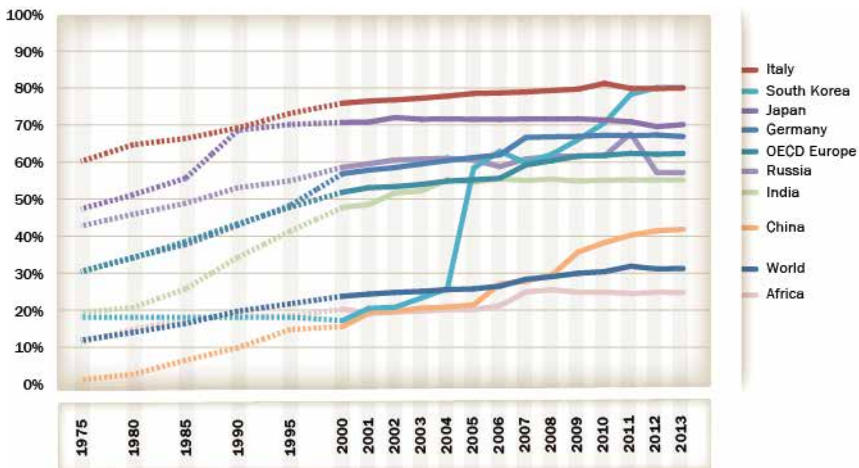
Source: Elaboration by IEA based on UIC (2015a)

Fig. 8: **Railway freight transport activity by geographic area, 1975-2013 (trillion tkm)**



Source: Elaboration by IEA based on UIC (2015a)

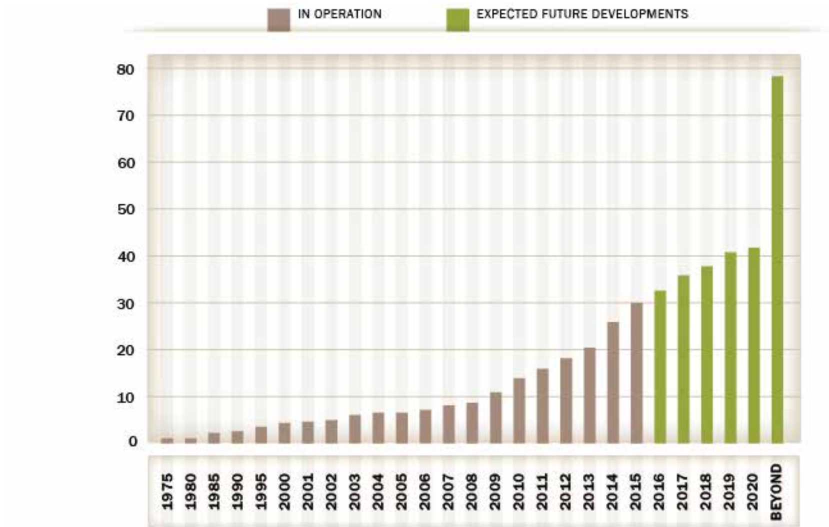
Fig. 9: **Share of electrified railway tracks in selected countries and geographic areas, 1975-2013**



Note: The USA are not displayed in this chart because of a lack of data.

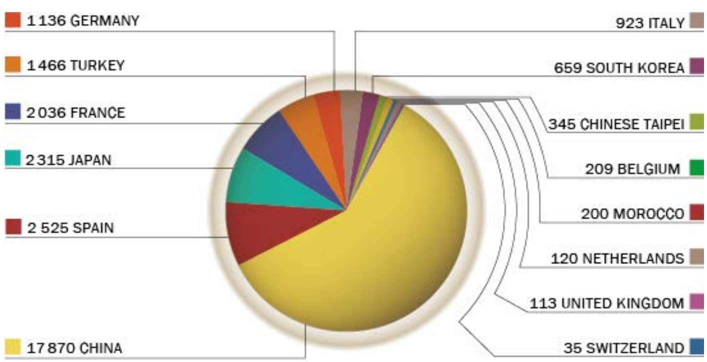
Source: Elaboration by IEA based on UIC (2015a)

Fig. 10: **Global high-speed lines (>250 km/h) in operation and expected future developments, 1975-2015 (thousand km)**



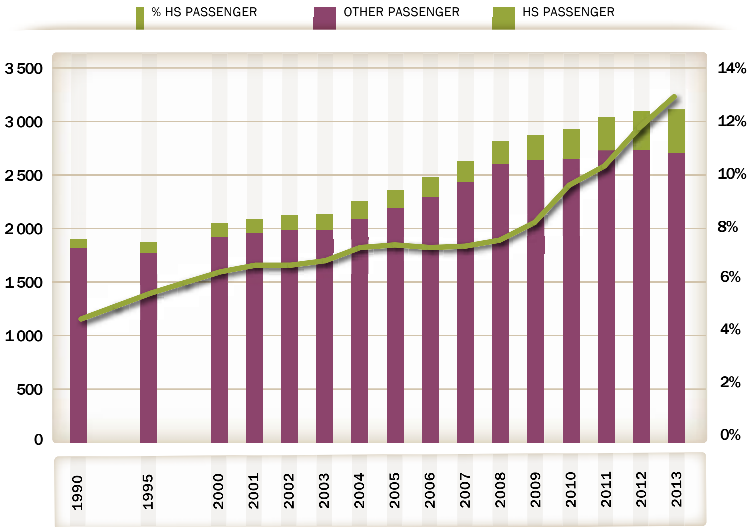
Source: Elaboration by IEA on UIC (2015a)

Fig. 11: **High-speed lines (>250 km/h) in operation by country (km), 2015**



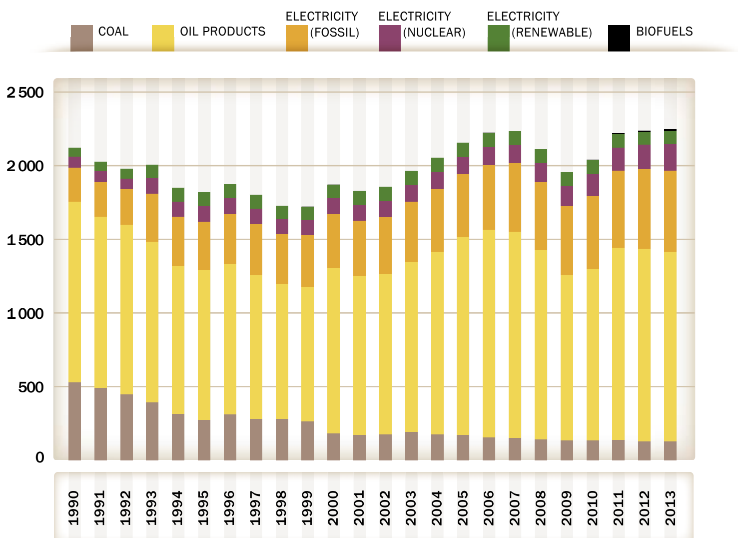
Source: Elaboration by Susdef on IEA and UIC (2015a)

Fig. 12: **High-speed activity as a share of total passenger railway activity, 1990-2013 (billion pkm)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 13: **Railway final energy consumption by fuel, 1990-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2015b)

Table 2: **World railway energy fuel mix, 1990-2013**

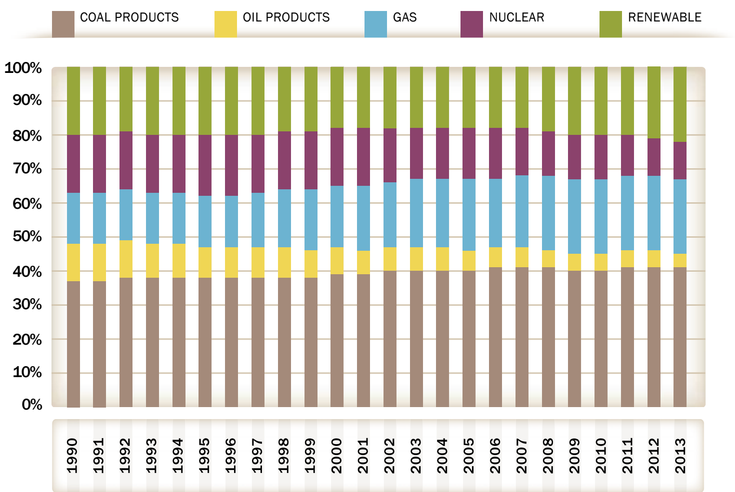
ENERGY MIX BY SOURCE	1990	2013
OIL PRODUCTS	58.0%	57.3%
COAL PRODUCTS	24.8%	5.6%
BIOFUELS	0.0%	0.7%
ELECTRICITY	17.2%	36.4%
of which Fossil	10.9%	24.5%
of which Nuclear	2.9%	3.9%
of which Renewable	3.4%	8.0%

SUMMARY BY SOURCE TYPE	1990	2013
FOSSIL SOURCE	93.7%	87.4%
NUCLEAR	2.9%	3.9%
RENEWABLE	3.4%	8.7%

Note: See Methodology Notes p. 109

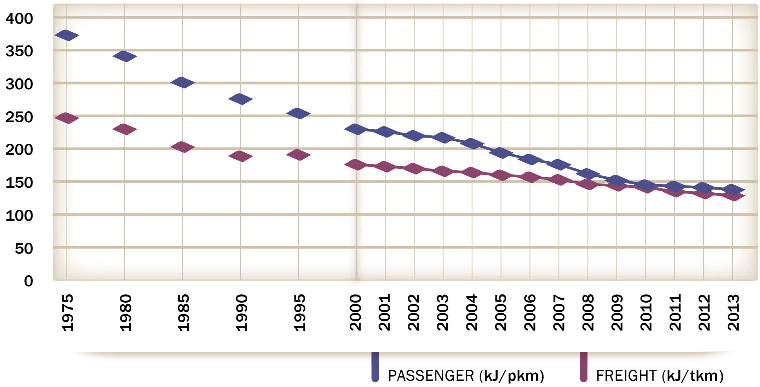
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 14: **World electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

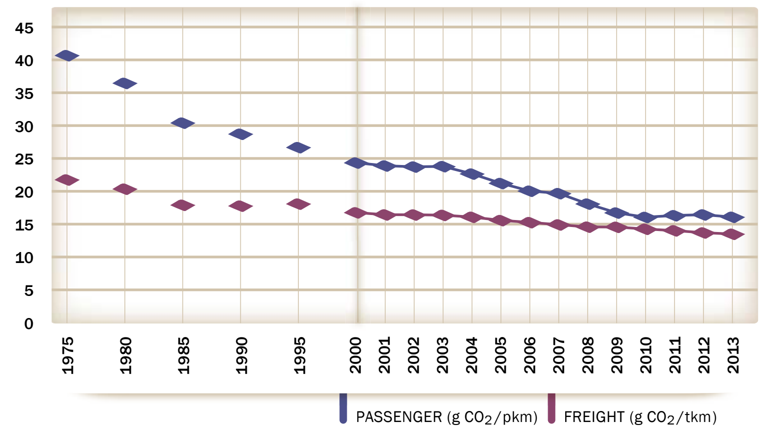
Fig. 15: **Railway specific energy consumption, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Fig. 16: **Railway specific CO_2 emissions, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Europe (EU28)

Key Facts

- Transport is the main source of CO_2 emissions in the European Union: it was responsible for 1.1 billion tCO_2 emissions in 2013 (31.6% of the European Union's total CO_2 emissions). The rail sector accounted for 1.5% of transport-related CO_2 (about 17 million tCO_2), while the rail share in transport activity of passengers and goods was 9.1% in 2013.

- The contribution of rail to transport emissions has decreased by more than half since 1990.

- The rail sector used 220 PJ of energy in 2013, 70% of which was provided by electricity.

- The EU railway energy fuel mix shows an increase of renewable sources from 7.6% in 1990 to about 20% in 2013.

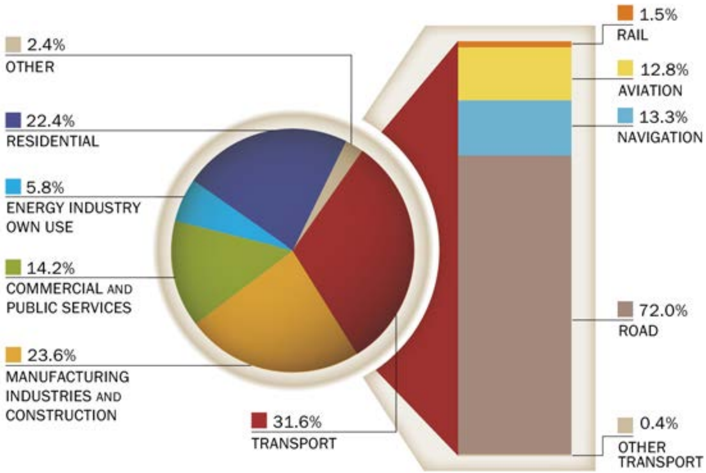
- 391 billion passenger-km were transported by rail in 2013. High speed rail accounted for 29% of this activity, seven times more than in 1990.

- The electrified railway network has doubled in length between 1975 and 2013, totaling 221 000 km of tracks in 2013. The share of electrified tracks in the total railway network reached 61% in 2013.

- Railway specific energy consumption dropped by 19.6% for passenger services and by 22.3% for freight services between 1990 and 2013.

- Railway specific CO_2 emissions fell by 41% for passenger services and 46% for freight services between 1990 and 2013.

Fig. 17: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

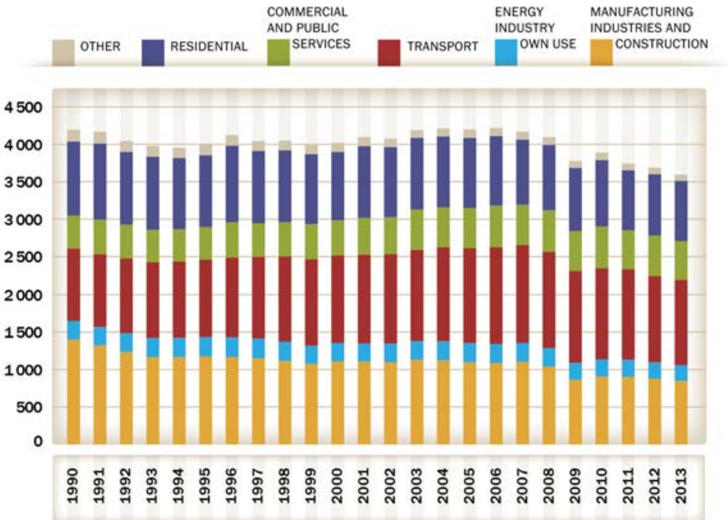
Source: Elaboration by Susdef based on IEA (2015a) and UIC (2015b)

Table 3: **EU28 transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	82.8%	51.1%	71.9%
AVIATION	9.0%	0.1%	5.9%
NAVIGATION	0.6%	36.9%	13.1%
RAIL	7.6%	11.9%	9.1%

Source: Elaboration by Susdef based on EC (2015) and UIC (2015a)

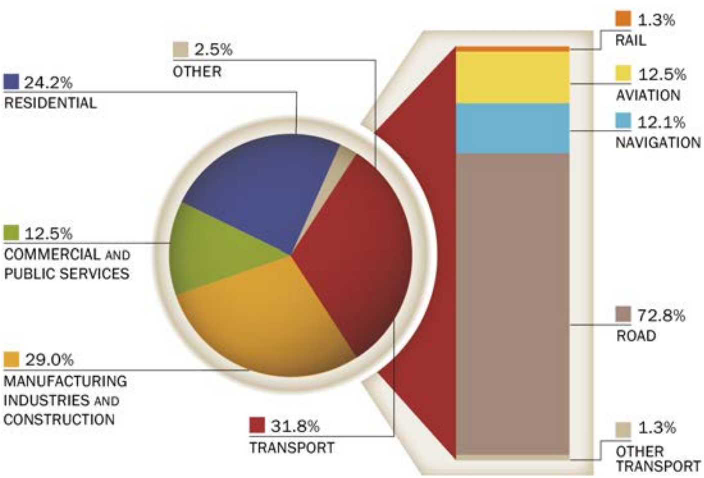
Fig. 18: **Total CO_2 emissions from fuel combustion by sector, 1990-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.

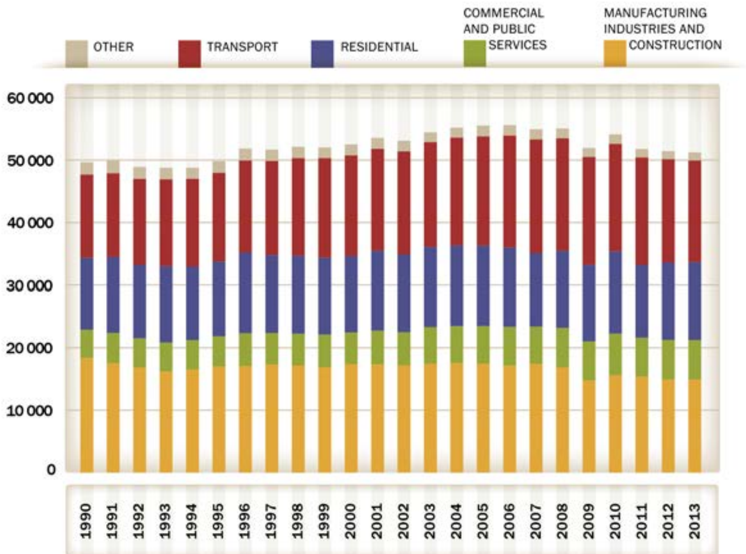
Source: Elaboration by Susdef based on IEA (2015a) and UIC (2015b)

Fig. 19: **Share of final energy consumption by sector, 2013**



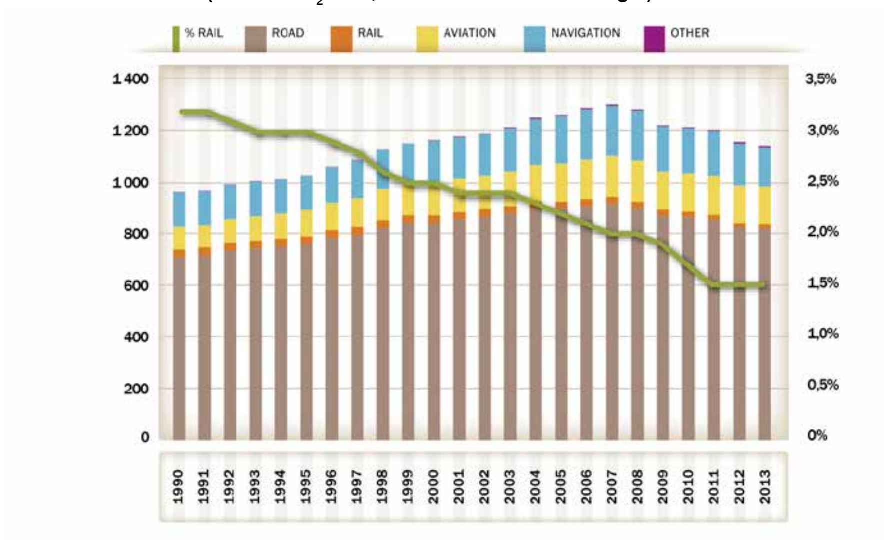
Source: Elaboration by Susdef based on IEA (2015b) and UIC (2015b)

Fig. 20: **Total final energy consumption by sector, 1990-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b) and UIC (2015b)

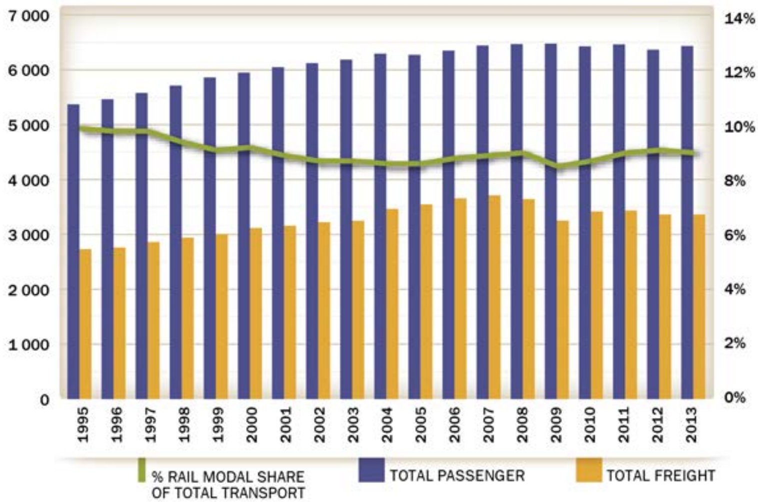
Fig. 21: **Transport sector CO_2 emissions by mode, 1990-2013 (million tCO_2 - left, share of rail over total - right)**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

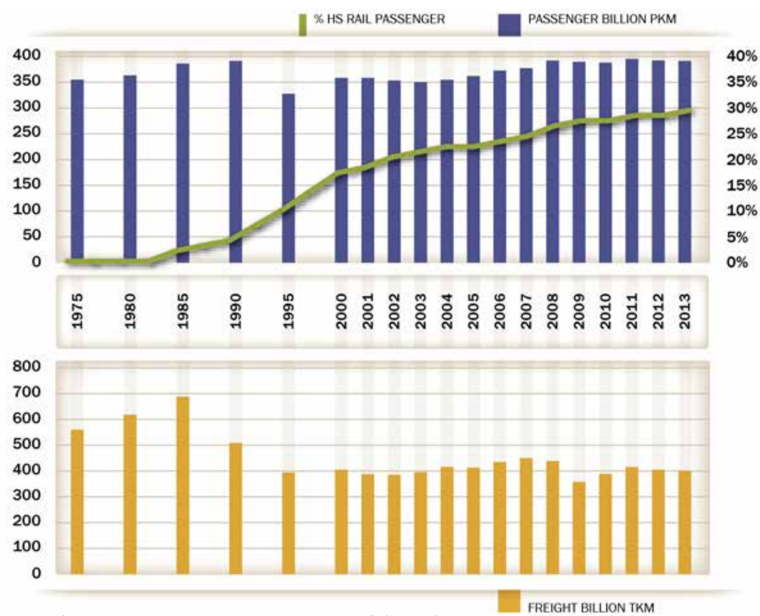
Source: Elaboration by Susdef based on IEA (2015a) and UIC (2015b)

Fig. 22: **Passenger and freight transport activity - all modes, 1995-2013 (billion pkm and tkm – left, share of rail over total – right)**



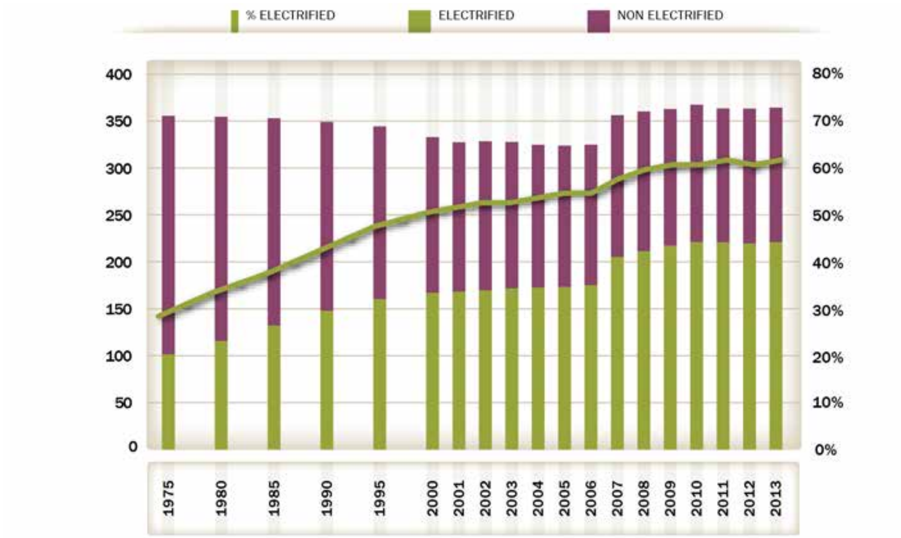
Source: Elaboration by Susdef based on EC (2015) and UIC (2015a)

Fig. 23: **Passenger and freight railway activity and High-Speed activity as a share of total passenger railway activity (%), 1975-2013**



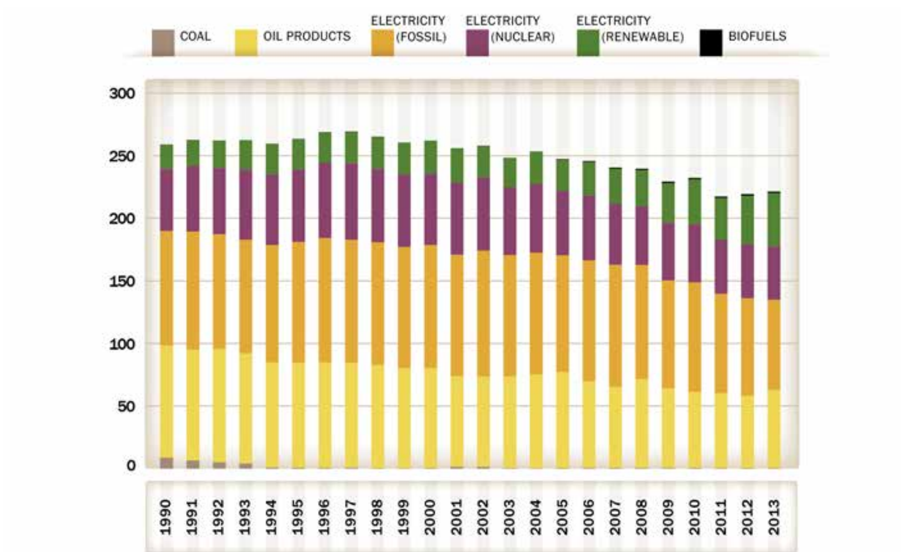
Source: Elaboration by IEA based on UIC (2015a)

Fig. 24: **Length and share of electrified and non-electrified railway tracks, 1975-2013 (thousand km)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 25: **Railway final energy consumption by fuel, 1990-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2015b) and UIC (2015b)

Table 4: **EU28 railway energy fuel mix, 1990-2013**

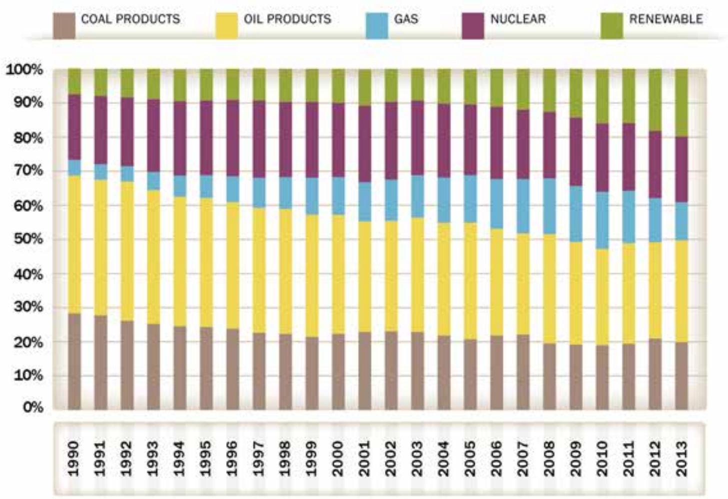
ENERGY MIX BY SOURCE	1990	2013
OIL PRODUCTS	34.6%	28.3%
COAL PRODUCTS	3.3%	0.2%
BIOFUELS	0.0%	0.4%
ELECTRICITY	62.1%	71.1%
of which Fossil	35.3%	32.4%
of which Nuclear	19.2%	19.3%
of which Renewable	7.6%	19.4%

SUMMARY BY SOURCE TYPE	1990	2013
FOSSIL SOURCE	73.2%	60.9%
NUCLEAR	19.2%	19.3%
RENEWABLE	7.6%	19.8%

Note: See Methodology Notes p. 109

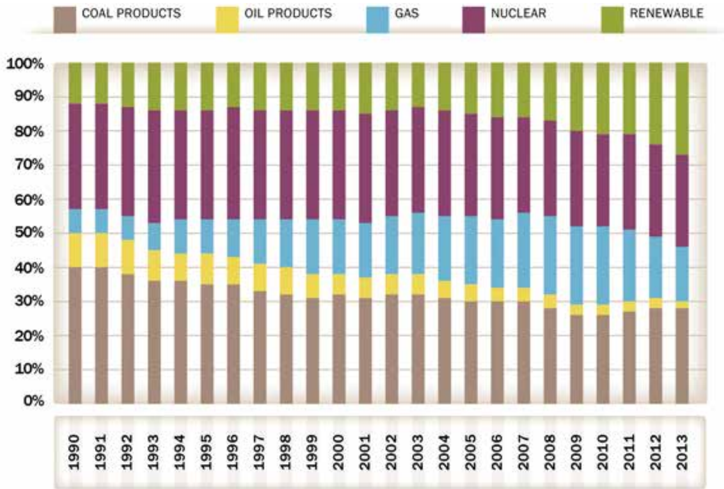
Source: Elaboration by Susdef based on IEA (2015b) and UIC (2015b)

Fig. 26: **EU28 Railway energy fuel mix evolution, 1990-2013**



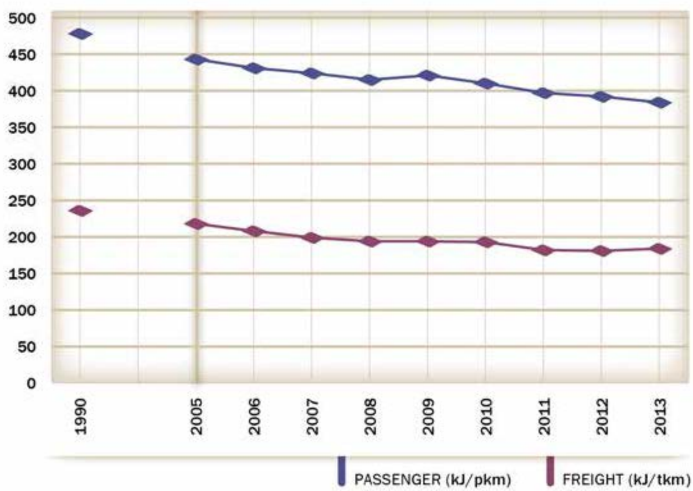
Source: Elaboration by Susdef based on IEA (2015b) and UIC (2015b).

Fig. 27: **EU28 electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

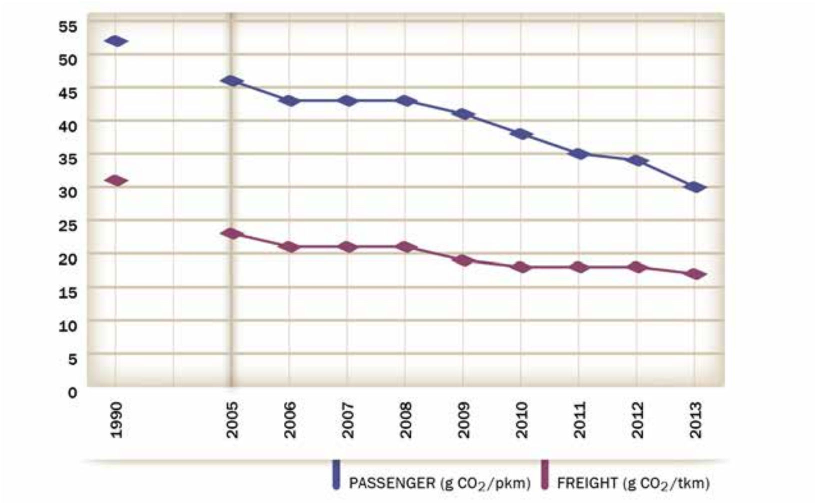
Fig. 28: **Railway specific energy consumption, 1990-2013**



Note: See Methodology Notes p. 109

Source: UIC (2015b)

Fig. 29: **Railway specific CO_2 emissions, 1990-2013**



Note: See Methodology Notes p. 109

Source: UIC (2015b)

USA

Key Facts

- In the USA, the transport sector was responsible for emitting 5.2 billion tCO_2 (35% of total CO_2 emissions) in 2013, representing the largest source of CO_2 emissions of the country. The USA transport sector has the largest contribution to its national total in terms of CO_2 emissions of the countries and regions examined in this Handbook.

- 2.2% of transport CO_2 emissions were caused by the rail sector (about 40 million tCO_2).

- 0.1% of passenger-km and 33% of goods (in tonne-km) were transported by rail in 2013.

- The rail sector used about 540 PJ of final energy in 2013, of which 92.8% were provided by oil products, because of the low electrification rate of US railway lines.

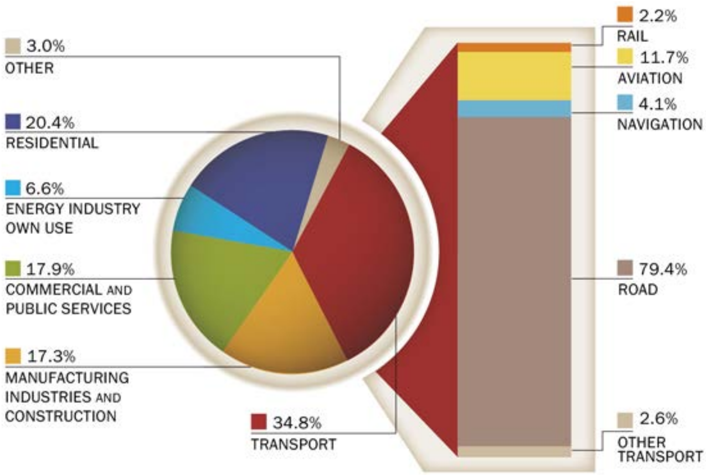
- USA railways used close to 3% of biofuels (15 PJ) in their energy mix in 2013, the highest share among global railways.

- Both passenger and freight transport activity increased between 1975 and 2013. Rail freight activity has more than doubled while rail passenger activity has increased by 69%, since 1975.

- Between 1975 and 2013, energy consumption per passenger-km decreased by 32% and energy consumption per freight tonne-km decreased by 58%.

- CO_2 emissions per passenger-km (passenger specific emissions) decreased by 28% between 1975 and 2013, while freight specific emissions decreased by 58% in the same period.

Fig. 30: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity/heat production are reallocated to rail.

Source: Elaboration by Susdef based on IEA (2015a)

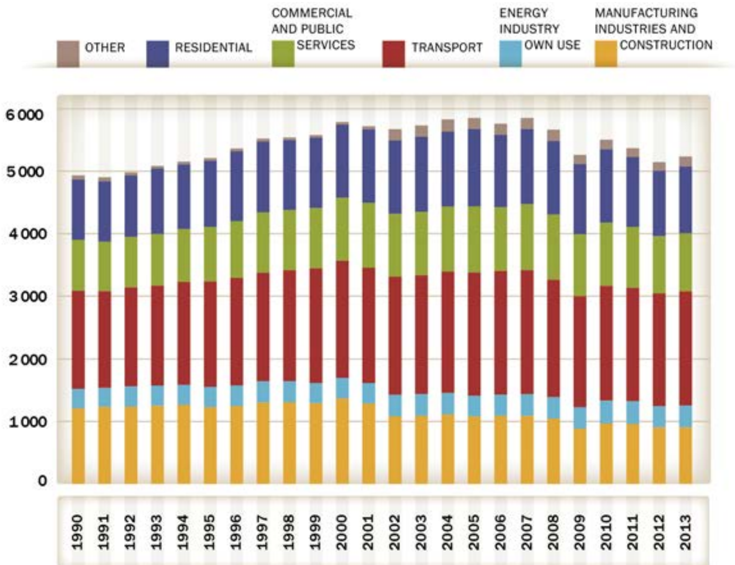
Table 5: **USA transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	87.9%	56.8%	72.5%
AVIATION	12.0%	0.2%	6.2%
NAVIGATION	0.0% *	10.4%	5.1%
RAIL	0.1%	32.6%	16.2%

* **Note**: Navigation's passenger activity has a value of 0.03%, corresponding to 647 million passenger-km.

Source: Elaboration by Susdef based on UIC (2015a) and NTS (2015)

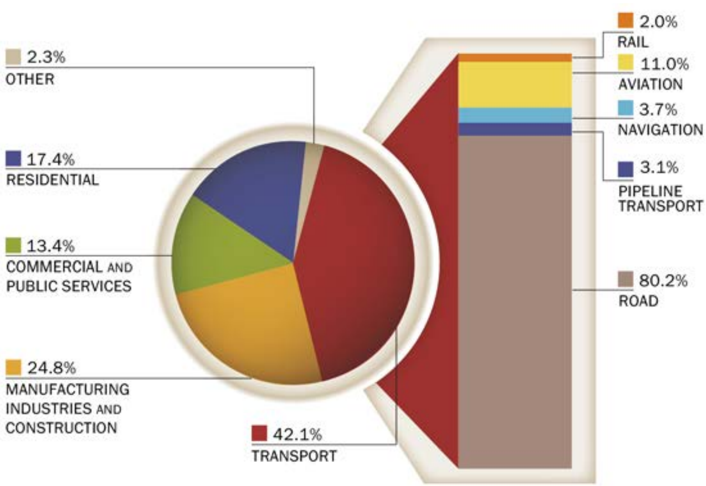
Fig. 31: **Total CO_2 emissions from fuel combustion by sector, 1990-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.

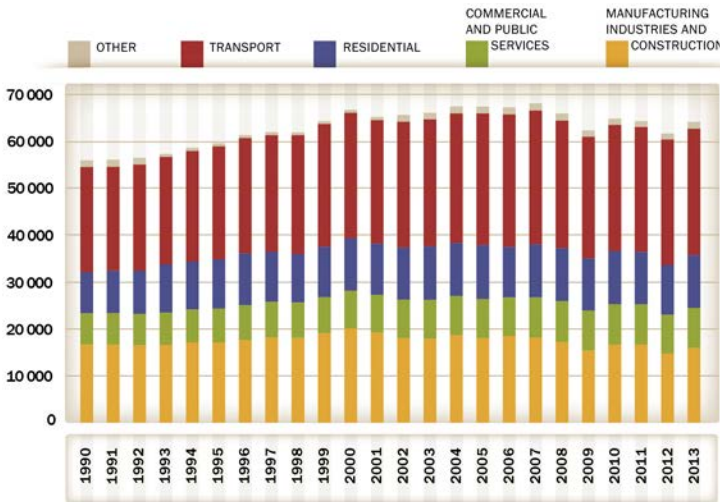
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 32: **Share of final energy consumption by sector, 2013**



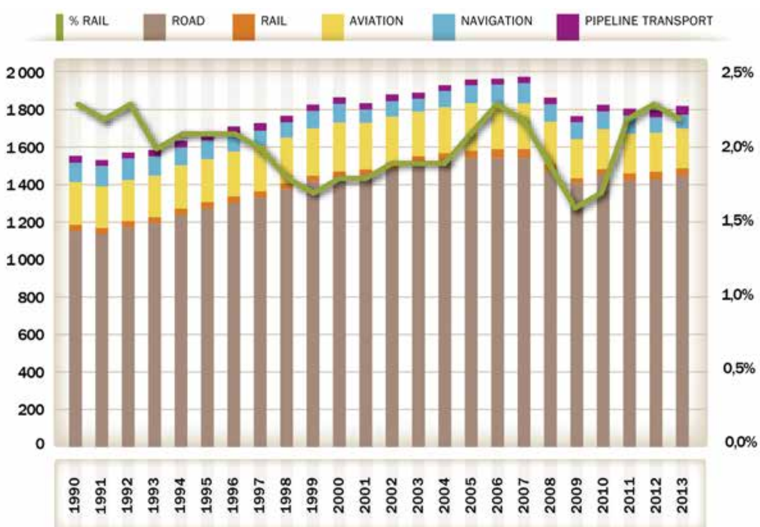
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 33: **Total final energy consumption by sector, 1990-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b)

Fig. 34: **Transport sector CO_2 emissions by mode, 1990-2013 (million tCO_2 - left, share of rail over total - right)**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

Source: Elaboration by Susdef based on IEA (2015a)

Fig. 35: **Passenger and freight transport activity - all modes, 1990-2013 (billion pkm and tkm – left, share of rail over total – right)**

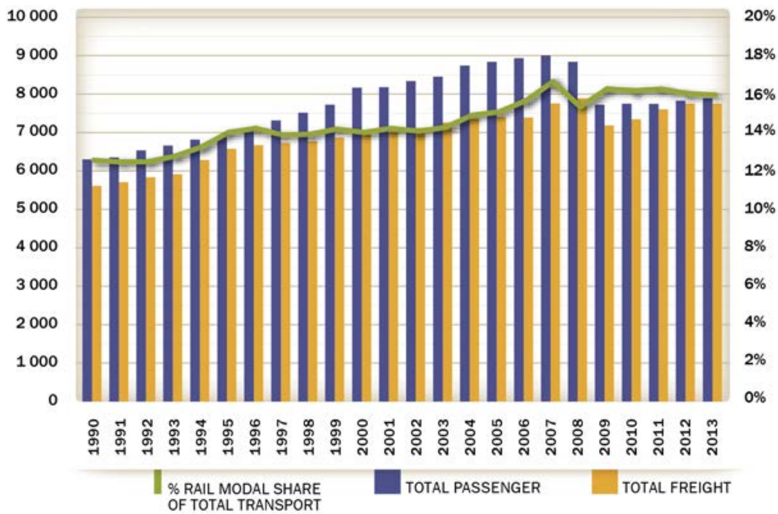
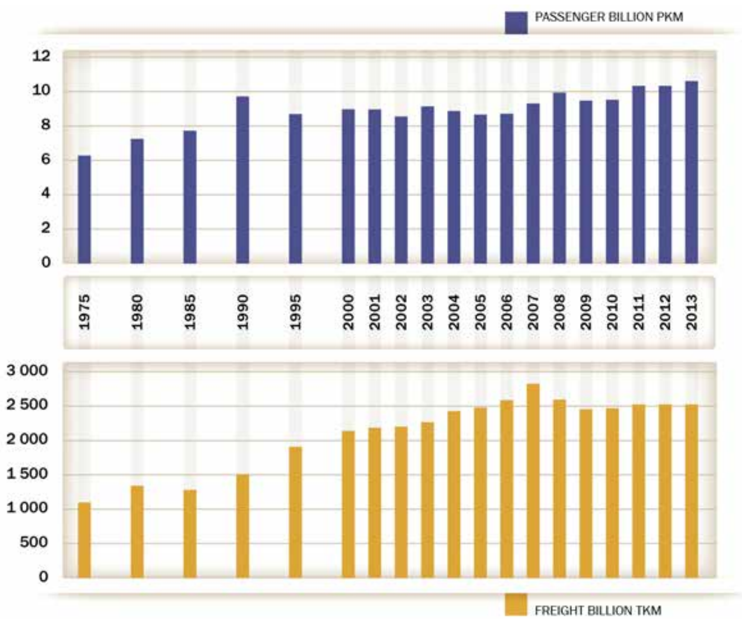
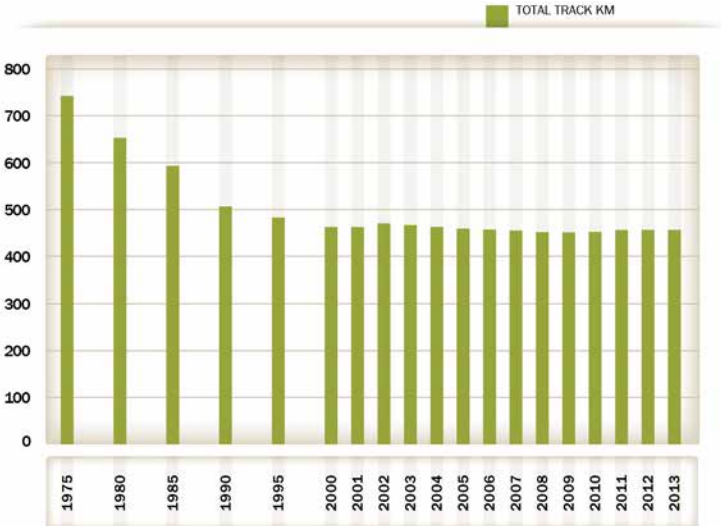


Fig. 36: **Passenger and freight railway activity, 1975-2013**



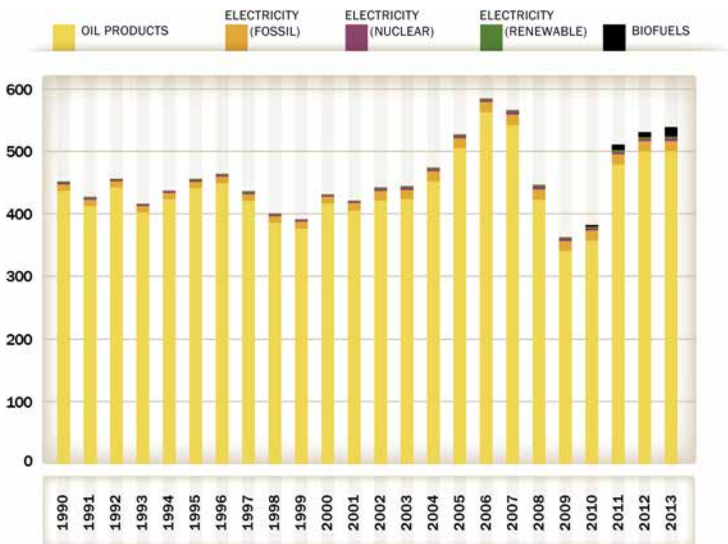
Source: Elaboration by IEA based on UIC (2015a)

Fig. 37: **Length of railway tracks, 1975-2013 (thousand km)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 38: **Railway final energy consumption by fuel, 1990-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2015b)

Table 6: **USA railway energy fuel mix, 1990-2013**

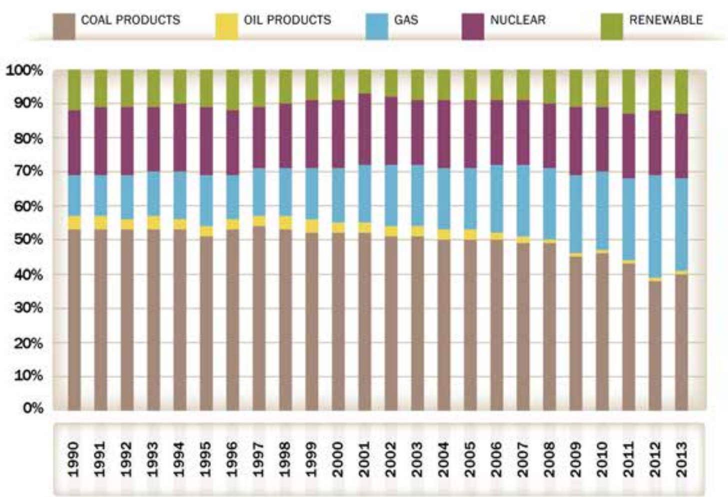
ENERGY MIX BY SOURCE	1990	2013
OIL PRODUCTS	96.7%	92.8%
BIOFUELS	0.0%	2.7%
ELECTRICITY	3.3%	4.5%
of which Fossil	2.3%	3.0%
of which Nuclear	0.6%	0.9%
of which Renewable	0.4%	0.6%

SUMMARY BY SOURCE TYPE	1990	2013
FOSSIL SOURCE	99.0%	95.8%
NUCLEAR	0.6%	0.9%
RENEWABLE	0.4%	3.3%

Note: See Methodology Notes p. 109

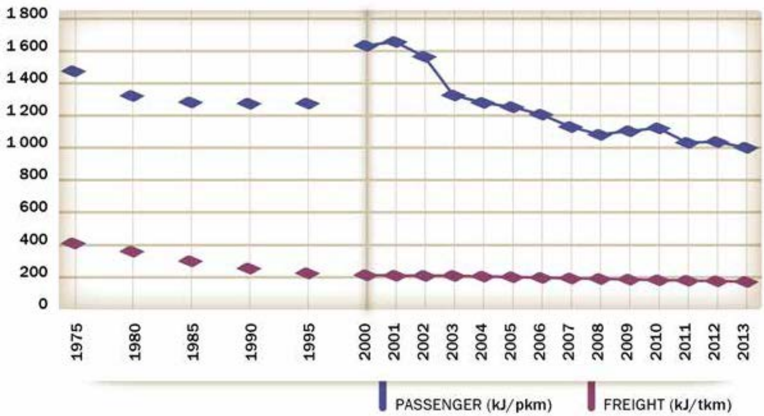
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 39: **National electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

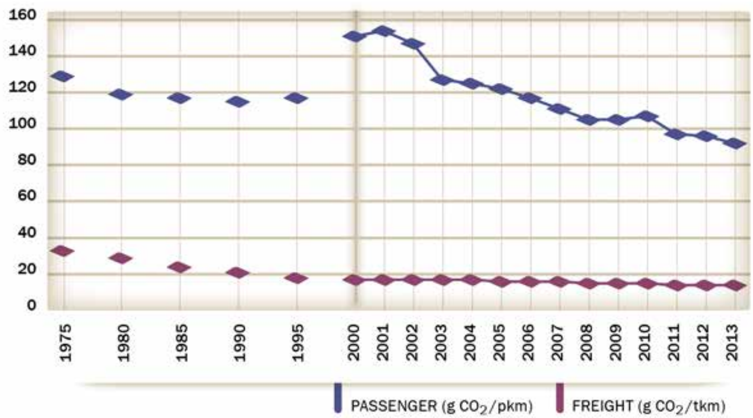
Fig. 40: **Railway specific energy consumption, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Fig. 41: **Railway specific CO_2 emissions, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Japan

Key Facts

- In Japan, the transport sector was responsible for 20% of total CO_2 emissions in 2013 and 4.6% of transport emissions were due to the rail sector.

- The share of rail in total transport activity was of 28.9% for passenger services and 5% for freight services.

- In 2013, 90% of the energy used in Japan was provided by electricity. The share of nuclear electricity in the national electricity production mix has decreased from 18% to 1% after the Fukushima accident of 2011. This has mainly been replaced by natural gas. As a result, CO_2 emissions in the railway sector have increased by 25% between 2010 and 2013.

- In the railway energy fuel mix, diesel consumption decreased from 17.4% to 10.3% between 1990 and 2013, which was replaced by the use of electricity.

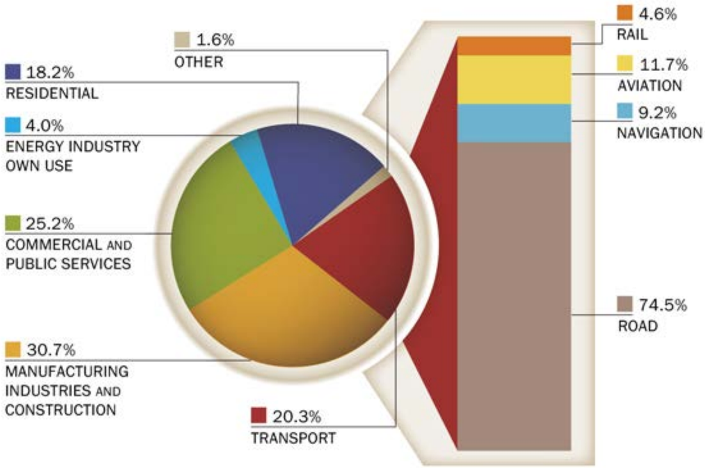
- 387 billion passenger-km were transported by rail in 2013, a 29% increase since 1975. High speed rail accounted for 23% of this activity.

- The electrified railway network covers about 19 000 km, and the proportion of electrified tracks increased by a 48% between 1975 and 2013. The electrified network represents 70% of the total rail network in Japan.

- Railway specific energy consumption dropped by 9% for passenger service and by 24% for freight between 1975 and 2013.

- Railway specific CO_2 emissions dropped by 8% for passenger services and 18% for freight services between 1975 and 2013.

Fig. 42: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

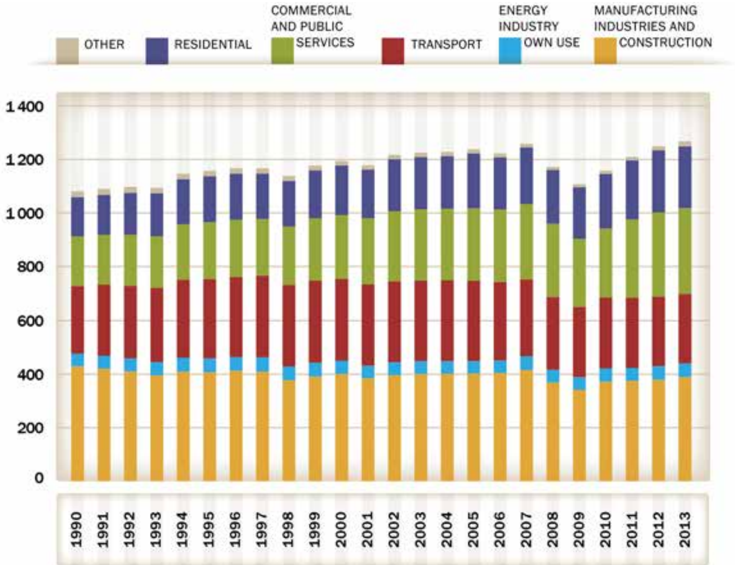
Source: Elaboration by Susdef based on IEA (2015a)

Table 7: **Japan transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	64.6%	50.8%	61.3%
AVIATION	6.3%	0.3%	4.8%
NAVIGATION	0.2%	43.9%	10.7%
RAIL	28.9%	5.0%	23.2%

Source: Elaboration by Susdef based on JSY (2015), IEA (2016b), UIC (2015a)

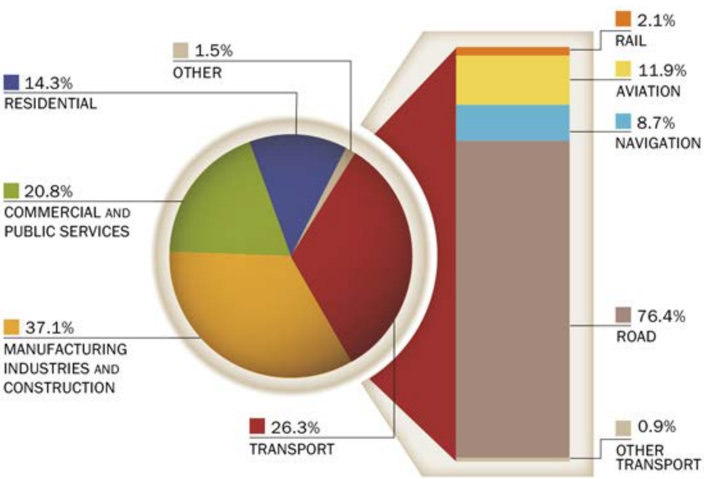
Fig. 43: **Total CO_2 emissions from fuel combustion by sector, 1990-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.

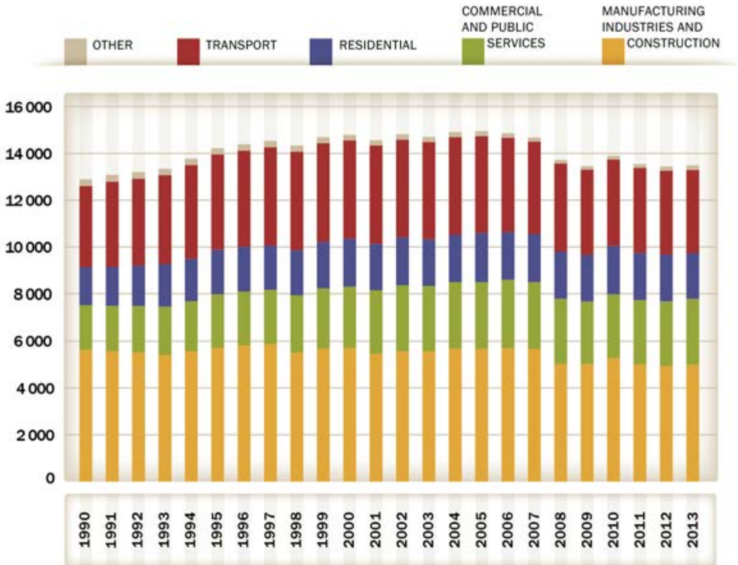
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 44: **Share of final energy consumption by sector, 2013**



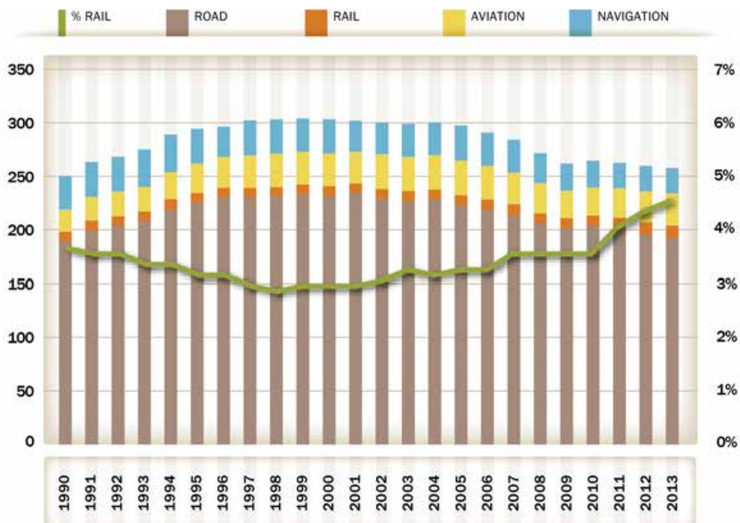
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 45: **Total final energy consumption by sector, 1990-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b)

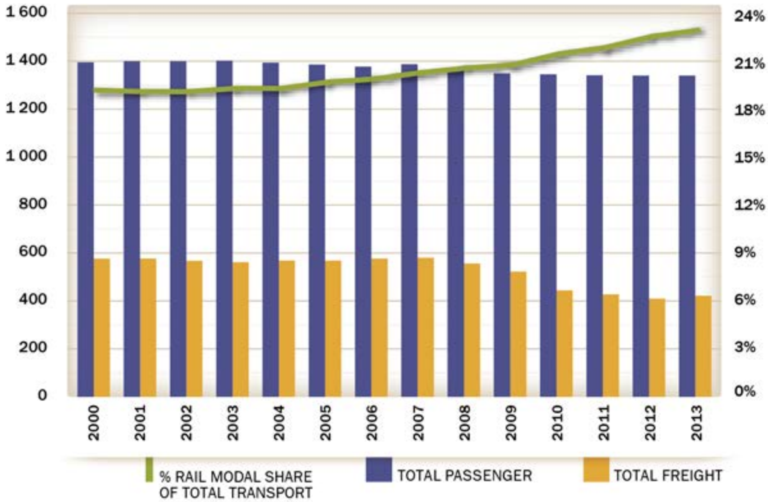
Fig. 46: **Transport sector CO_2 emissions by mode, 1990-2013 (million tCO_2 - left, share of rail over total - right)**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

Source: Elaboration by Susdef based on IEA (2015a)

Fig. 47: **Passenger and freight transport activity - all modes, 2000-2013 (billion pkm and tkm – left, share of rail over total – right)**

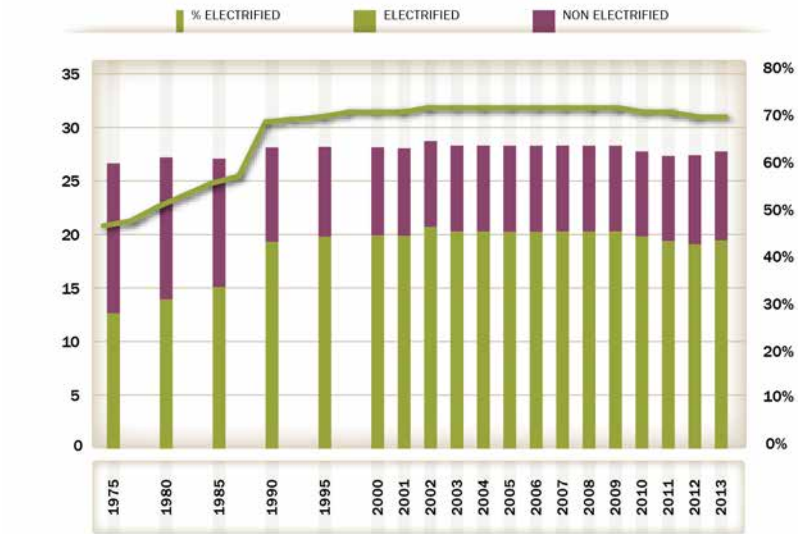


Source: Elaboration by Susdef based on JSY (2015), IEA (2016b), UIC (2015a)

Fig. 48: **Passenger and freight railway activity and High-Speed activity as a share of total passenger railway activity (%), 1975-2013**

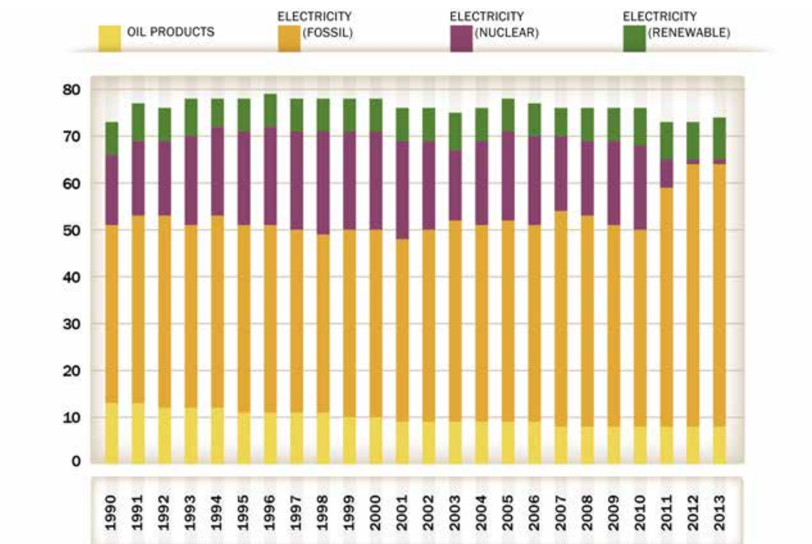
Source: Elaboration by IEA based on UIC (2015a)

Fig. 49: **Length and share of electrified and non-electrified railway tracks, 1975-2013 (thousand km)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 50: **Railway final energy consumption by fuel, 1990-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2015b)

Table 8: **Japan railway energy fuel mix, 1990-2013**

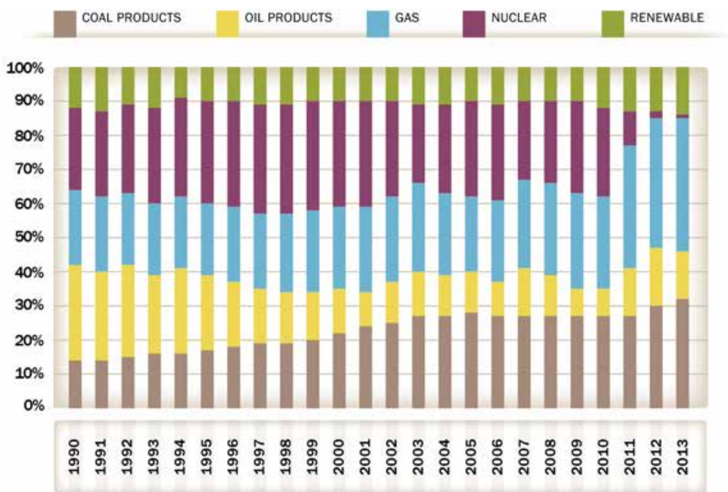
ENERGY MIX BY SOURCE	1990	2013
OIL PRODUCTS	17.4%	10.3%
ELECTRICITY	82.6%	89.7%
of which Fossil	52.5%	76.7%
of which Nuclear	20.0%	0.8%
of which Renewable	10.1%	12.2%

SUMMARY BY SOURCE TYPE	1990	2013
FOSSIL SOURCE	69.9%	87.0%
NUCLEAR	20.0%	0.8%
RENEWABLE	10.1%	12.2%

Note: See Methodology Notes p. 109

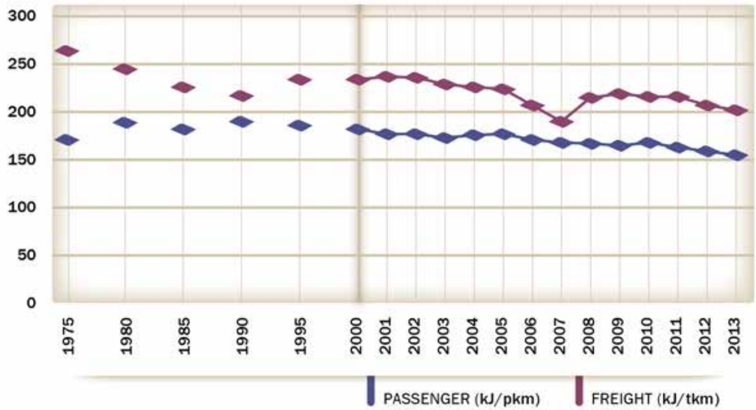
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 51: **National electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

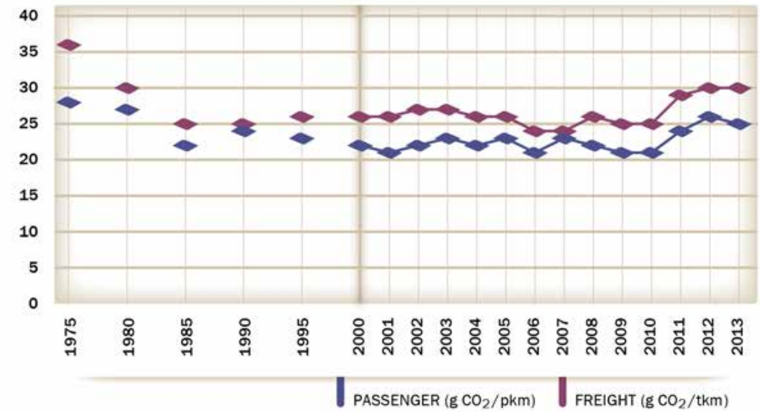
Fig. 52: **Railway specific energy consumption, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Fig. 53: **Railway specific CO_2 emissions, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Russian Federation

Key Facts

- The rail sector is responsible for 14% of transport's CO_2 emissions and 5.5% of transport's energy use. Rail's share of total transport activity reached 28.5% for passenger services and about 87% for freight services in 2013, making it the first transport mode in the country.

- Pipeline transport is the second largest source of CO_2 in transport (20.1% of total transport emissions) after road (46.5% of transport emissions), followed by rail with a contribution of 14% to total transport emissions.

- The amount of energy used in the transport sector was close to 250 PJ in 2013. The use of oil products in the railway energy fuel mix declined from 44.6% in 1995 to 29% in 2013.

- This decline in oil products use occurred in parallel with a growth in electricity use over the same period, from 55.4% in 1995 to 71% in 2013. The share of nuclear electricity in the electricity mix has doubled over the same period.

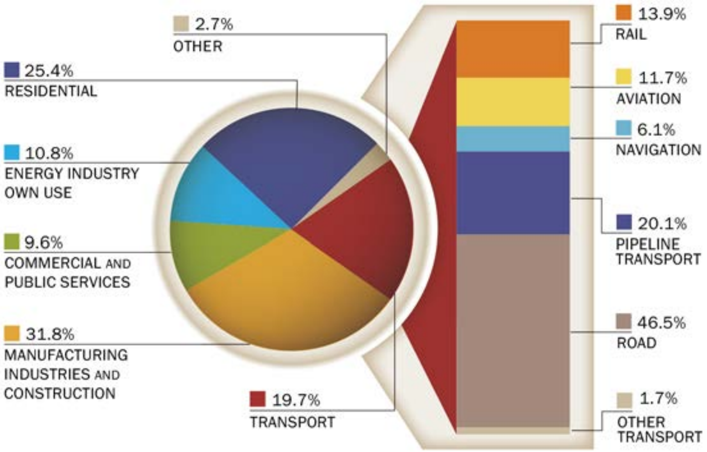
- 140 billion passenger-km and about 2 200 billion tonne-km were transported by rail in 2013. Freight rail activity has increased by 83% between 1995 and 2013.

- The Russian railway network extension, in terms of km of tracks, has increased by 58% between 1975 and 2013. Over the same period, the total length of electrified railway tracks has more than doubled and accounted for 57% of the total network in 2013.

- Railway specific energy consumption dropped by 20% for passenger services and by 46% for freight services between 1975 and 2013.

- Specific CO_2 emissions from rail freight services decreased by 25% between 1975 and 2013, while specific CO_2 emissions from rail passenger services increased from 19.9 gCO_2/pkm to 24.1 gCO_2/pkm in the same period.

Fig. 54: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

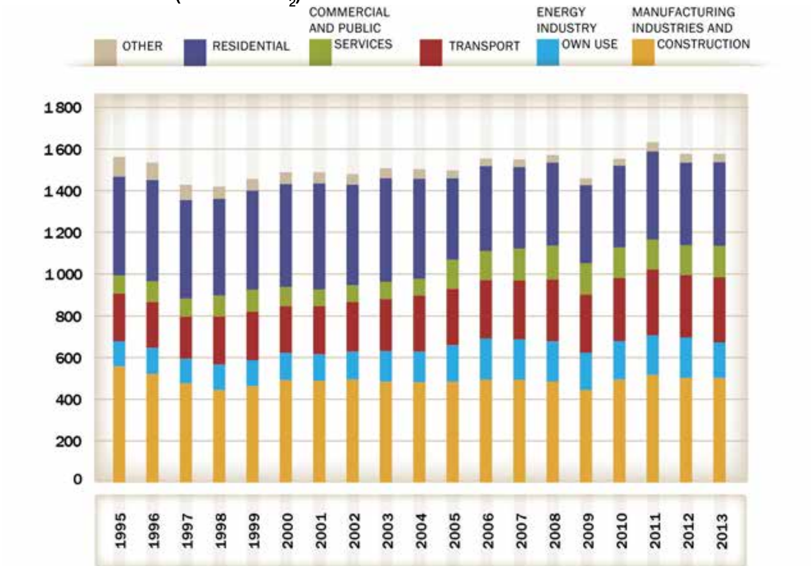
Source: Elaboration by Susdef based on IEA (2015a)

Table 9: **Russia transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	25.5%	9.8%	12.3%
AVIATION	45.9%	0.2%	7.6%
NAVIGATION	0.1%	3.1%	2.6%
RAIL	28.5%	86.9%	77.5%

Source: Elaboration by Susdef based on OECD (2016), UIC (2015a) and Rosstat (2015)

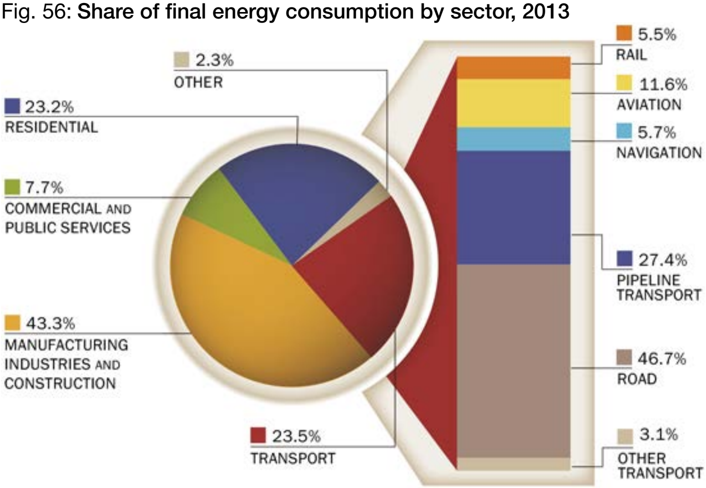
Fig. 55: **Total CO_2 emissions from fuel combustion by sector, 1995-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.

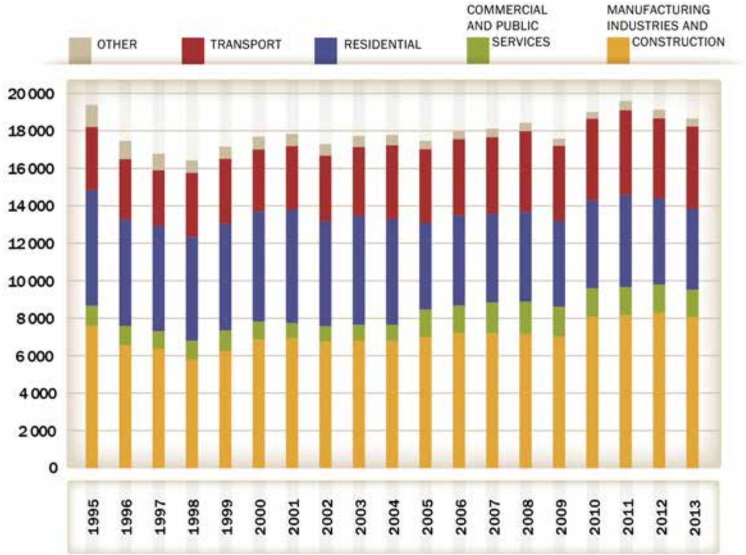
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 56: **Share of final energy consumption by sector, 2013**



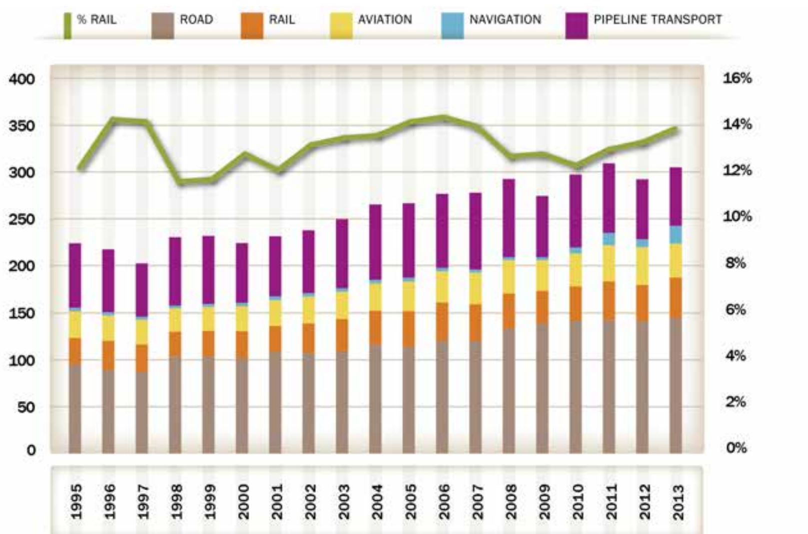
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 57: **Total final energy consumption by sector, 1995-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b)

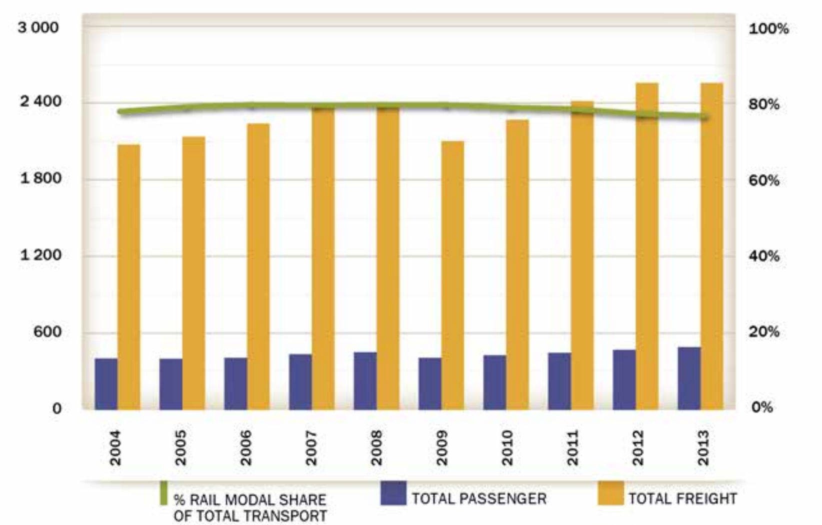
Fig. 58: **Transport sector CO_2 emissions by mode, 1995-2013 (million tCO_2 - left, share of rail over total - right)**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

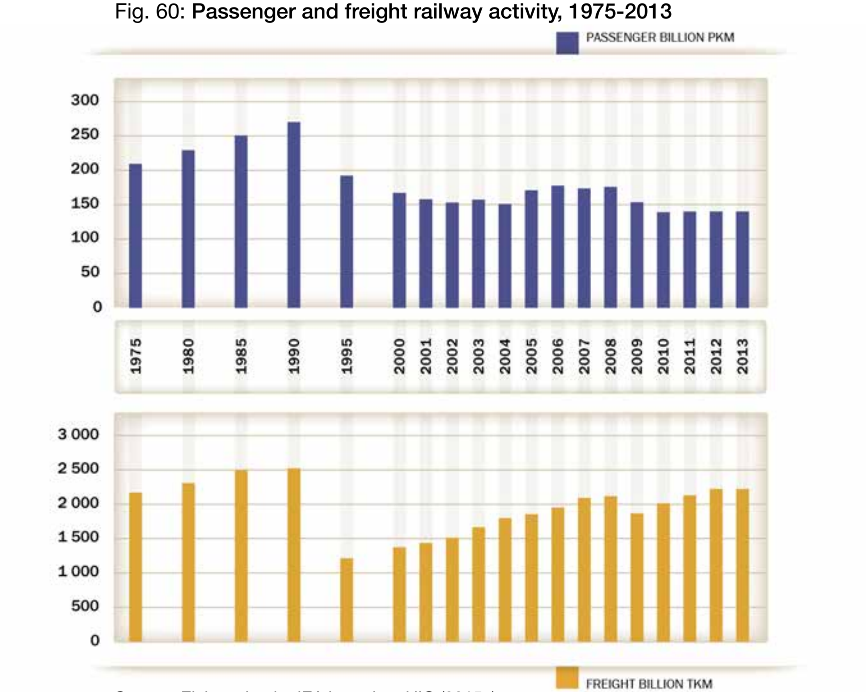
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 59: **Passenger and freight transport activity - all modes, 2004-2013 (billion pkm and tkm – left, share of rail over total – right)**



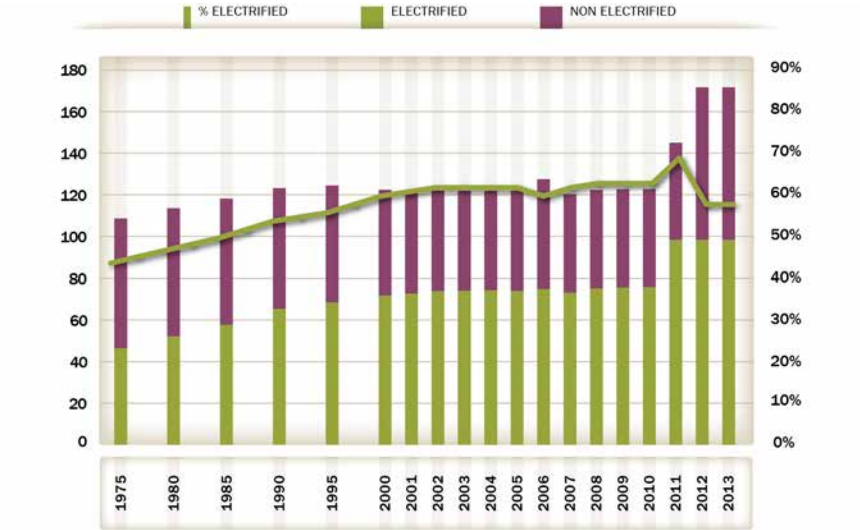
Source: Elaboration by Susdef based on OECD (2016), UIC (2015a) and Rosstat (2015)

Fig. 60: **Passenger and freight railway activity, 1975-2013**



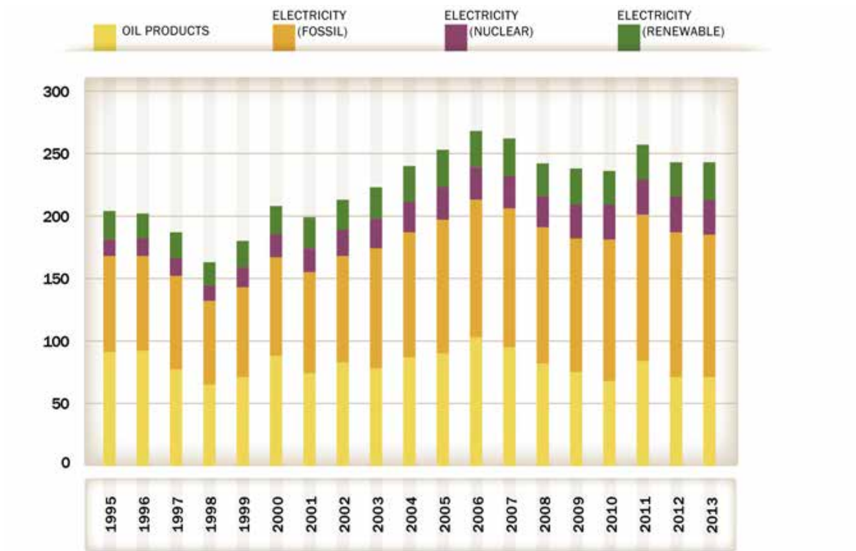
Source: Eleboration by IEA based on UIC (2015a)

Fig. 61: **Length and share of electrified and non-electrified railway tracks, 1975-2013 (thousand km)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 62: **Railway final energy consumption by fuel, 1995-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2015b)

Table 10: **Russia railway energy fuel mix, 1995-2013**

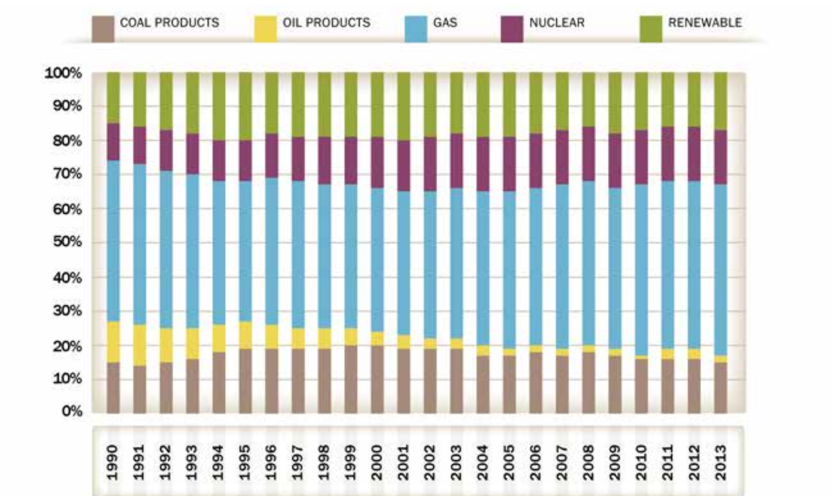
ENERGY MIX BY SOURCE	1995	2013
OIL PRODUCTS	44.6%	29.0%
ELECTRICITY	55.4%	71.0%
of which Fossil	37.6%	47.0%
of which Nuclear	6.4%	11.6%
of which Renewable	11.4%	12.4%

SUMMARY BY SOURCE TYPE	1995	2013
FOSSIL SOURCE	82.2%	76.0%
NUCLEAR	6.4%	11.6%
RENEWABLE	11.4%	12.4%

Note: See Methodology Notes p. 109

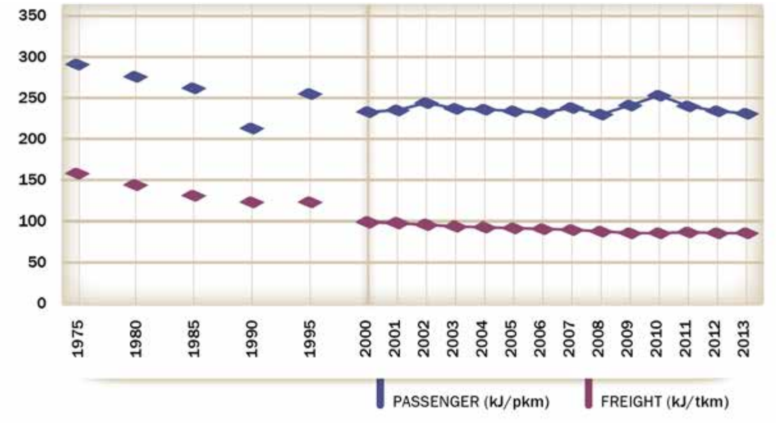
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 63: **National electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

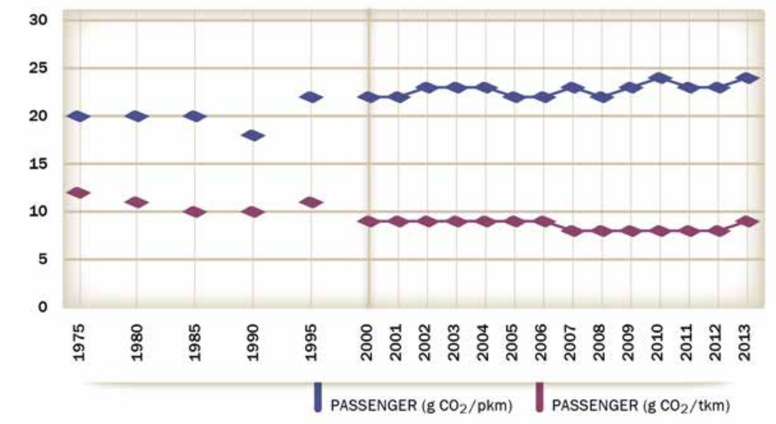
Fig. 64: **Railway specific energy consumption, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Fig. 65: **Railway specific CO_2 emissions, 1975-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

India

Key Facts

- The transport sector was responsible for 13.5% of total CO_2 emissions in 2013 (equal to 250 million tCO_2), increasing its share about 3.5 times from 1990. 9.7% of transport emissions were generated by the rail sector (amounting to about 24.7 million tCO_2). Rail's share of total transport activity was 12.6% for passengers transport, and 33.3%% for freight transport.

- The rail sector used about 170 PJ of energy in 2013, two thirds of which were provided by oil products. The share of coal products in the rail energy mix in 1990 was as high as 50% and it was entirely phased out by 1997.

- Over the same period, the use of oil products in Indian railways increased from 36.6% to 67.3% of the total energy mix, and the use of electricity grew from 8.5% to 32.7% of the total energy mix. The share of renewable electricity sources in the total energy mix also increased from 2.1% to 5.5% over that period.

- These changes in energy sources allowed for a reduction of the share of rail transport CO_2 emissions from 24% in 1990 to less than 10% in 2013, while rail activity doubled in the same period.

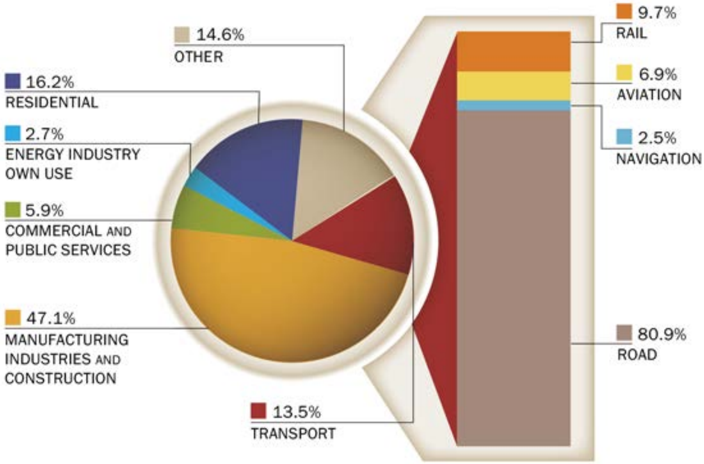
- India is the country with the highest rail passenger activity with over 1 trillion passenger-km carried in 2013. This number is seven times larger than what it was in 1975. Similarly, freight activity increased with a factor 5.5 between 1975 and 2013.

- The electrified railway network's length has tripled between 1975 and 2013. This electrification brought the share of electrified tracks in the total railway network to 55% in 2013.

- Rail's specific energy consumption has dropped by 42% for passenger services and by 27% for freight services between 2000 and 2013.

- Rail's specific CO_2 emissions fell by 37% for passenger services and by 24% for freight services between 2000 and 2013.

Fig. 66: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity/heat production are reallocated to rail.

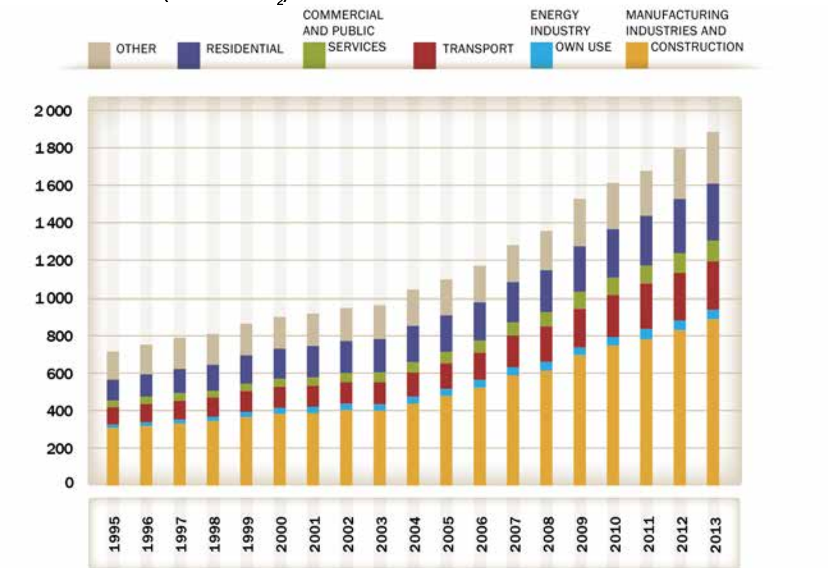
Source: Elaboration by Susdef based on IEA (2015a)

Table 11: **India transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	86.1%	66.4%	82.3%
AVIATION	1.3%	0.1%	1.0%
NAVIGATION	N.A.	0.2%	N.A.
RAIL	12.6%	33.3%	16.7%

Source: Elaboration by Susdef based on OECD (2016), UIC (2015a) and SYB (2015)

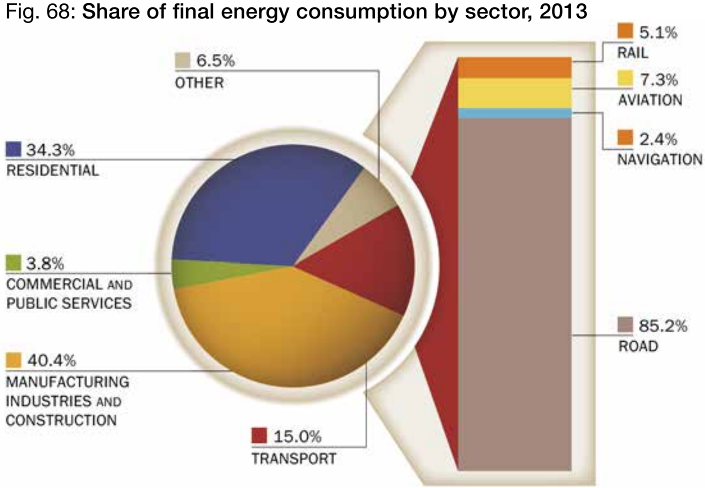
Fig. 67: **Total CO_2 emissions from fuel combustion by sector, 1995-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.

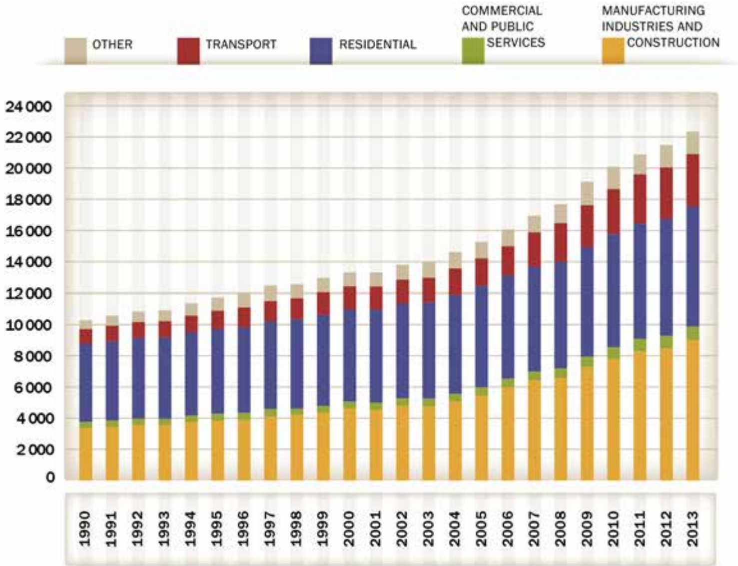
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 68: **Share of final energy consumption by sector, 2013**



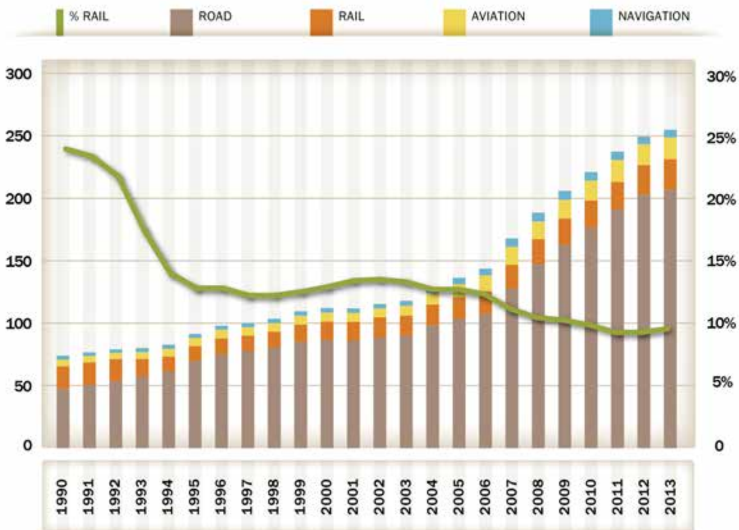
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 69: **Total final energy consumption by sector, 1990-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b)

Fig. 70: **Transport sector CO_2 emissions by mode, 1990-2013 (million tCO_2 - left, share of rail over total - right)**



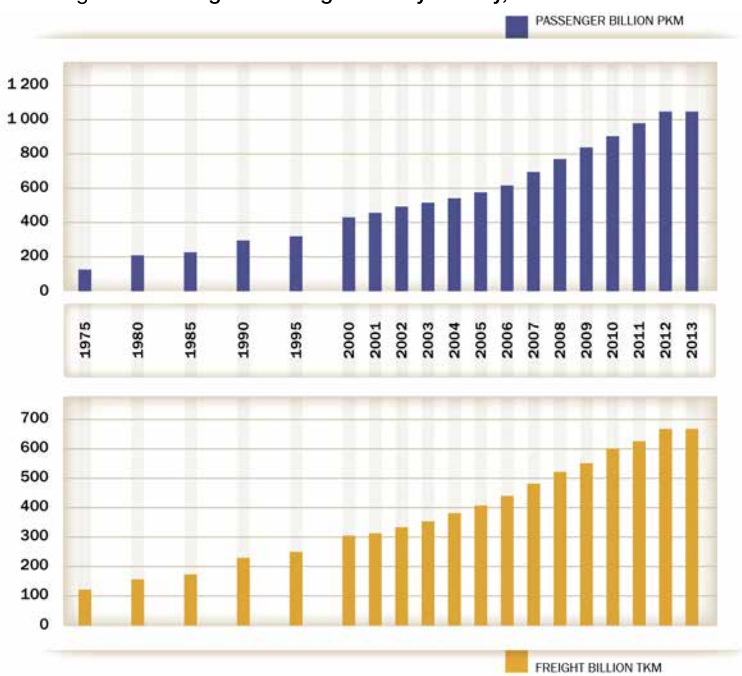
Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

Source: Elaboration by Susdef based on IEA (2015a)

Fig. 71: **Passenger and freight transport activity - all modes, 2005-2013 (billion pkm and tkm – left, share of rail over total – right)**

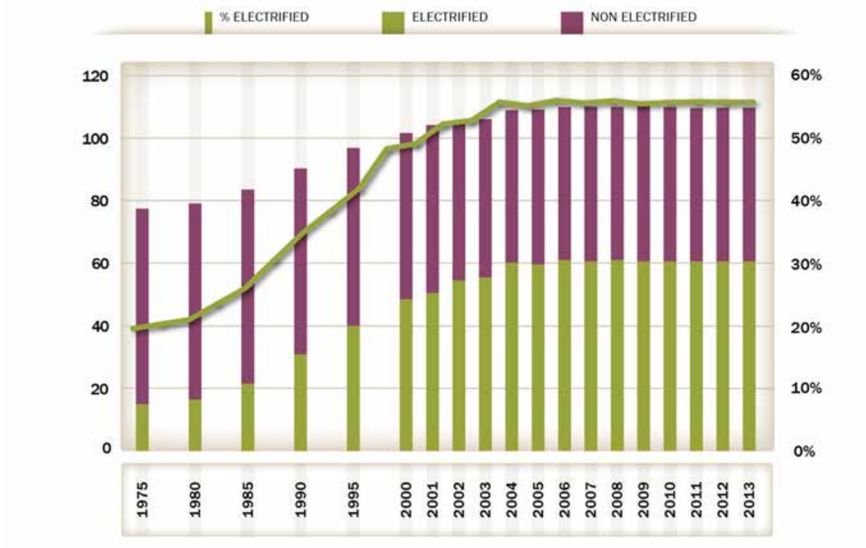
Source: Elaboration by Susdef based on OECD (2016), UIC (2015a) and SYB (2015)

Fig. 72: **Passenger and freight railway activity, 1975-2013**



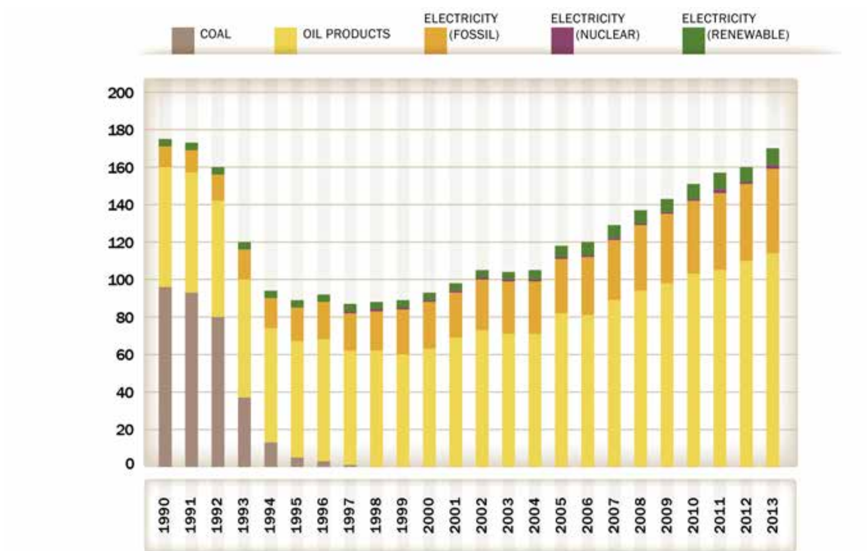
Source: Eleboration by IEA based on UIC (2015a)

Fig. 73: **Length and share of electrified and non-electrified railway tracks, 1975-2013 (thousand km)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 74: **Railway final energy consumption by fuel, 1990-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2015b)

Table 12: **India railway energy fuel mix, 1990-2013**

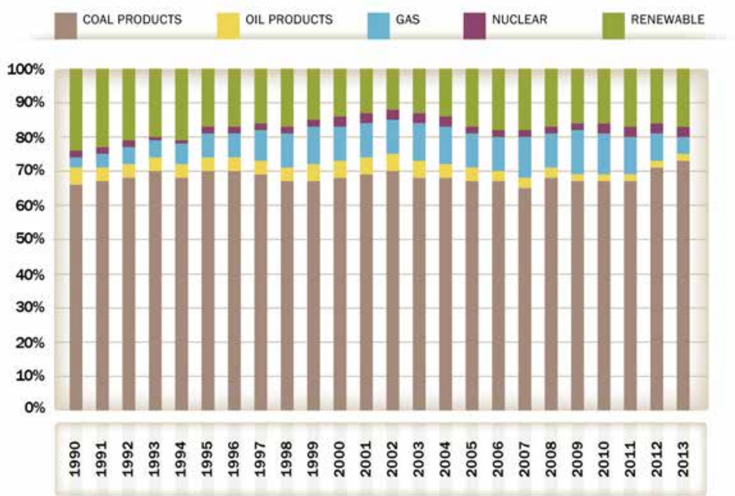
ENERGY MIX BY SOURCE	1990	2013
OIL PRODUCTS	36.6%	67.3%
COAL PRODUCTS	54.9%	0.0%
ELECTRICITY	8.5%	32.7%
of which Fossil	6.2%	26.3%
of which Nuclear	0.2%	0.9%
of which Renewable	2.1%	5.5%

SUMMARY BY SOURCE TYPE	1990	2013
FOSSIL SOURCE	97.7%	93.6%
NUCLEAR	0.2%	0.9%
RENEWABLE	2.1%	5.5%

Note: See Methodology Notes p. 109

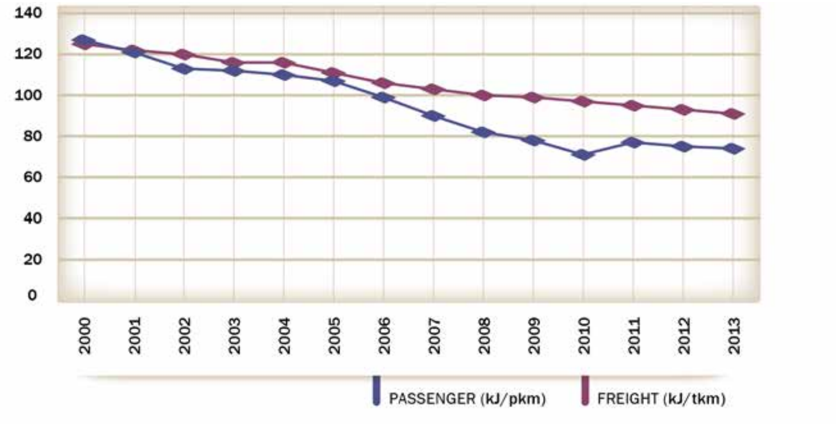
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 75: **National electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

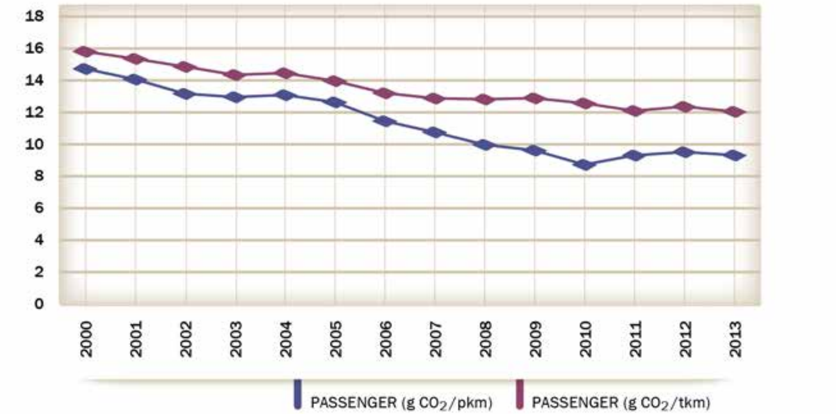
Fig. 76: **Railway specific energy consumption, 2000-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Fig. 77: **Railway specific CO_2 emissions, 2000-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

People's Republic of China

Key Facts

- CO_2 emissions from the transport sector increased by a factor 3 between 2000 and 2013, mainly because of the rapid growth of the road transport sector, which CO_2 emissions increased from 186 to 611 million tCO_2 within the same period.

- The rail sector was responsible for 8.2% of transport CO_2 emissions and 4.7% of China's energy use in 2013. In the same year, the contribution of CO_2 emissions from rail activity to China's total transport CO_2 emissions amounted to 10.1% for passenger services and 17.2% for freight services.

- The share of the rail sector's CO_2 emissions decreased from 37% of total transport CO_2 emissions in 1990 to less than 10% in 2013, mainly due to the growth of road transport and the increasing use of electricity in railway operations.

- Rail's final energy use was close to 273 PJ in 2013, of which 36% results from oil products and at 64% from electricity. The share of electricity use in the rail sector grew with a factor 3 between 2000 and 2013, with an increasing contribution of renewable electricity sources in the same period (from 3.8% in 2000 to 13.1% in 2013).

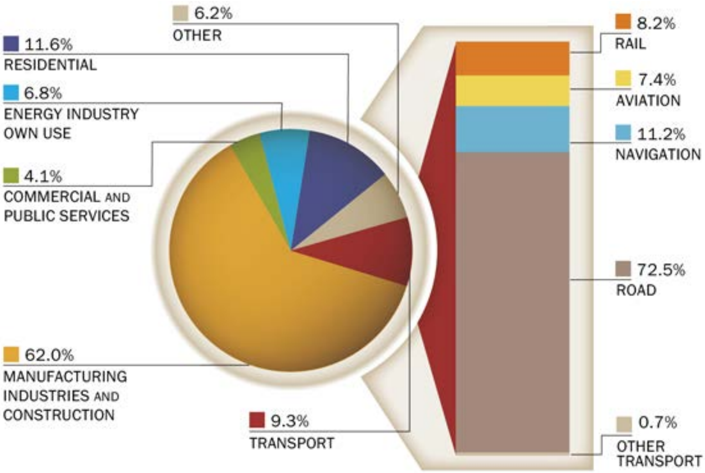
- With more than 2.5 trillion tonne-km in 2013, China has the highest freight rail activity globally (with nearly a 6-fold increase between 1975 and 2013). Within the same period, passenger rail activity increased with a factor 8 reaching a total of 794 billion passenger-km.

- The share of electrified tracks in the railway network has increased progressively from 1% in 1975 to 42% in 2013. A rapid development of high-speed lines took place in the past fifteen years: by 2015, China had built about 18 000 km of high-speed lines, while the first high-speed line was completed in 2003. Consequently, a rapid increase of high-speed passenger activity has taken place, from 2% of total rail passenger activity in 2009 to 18% in 2013.

- Railway specific energy consumption dropped by 44% for passenger services and by 52% for freight services between 1990 and 2013.

- The passenger carbon intensity has remained fairly stable with a decrease of -7% from 1990 to 2013, while the freight carbon intensity has dropped by -32% in the same period.

Fig. 78: **Share of CO_2 emissions from fuel combustion by sector, 2013**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity/heat production are reallocated to rail.

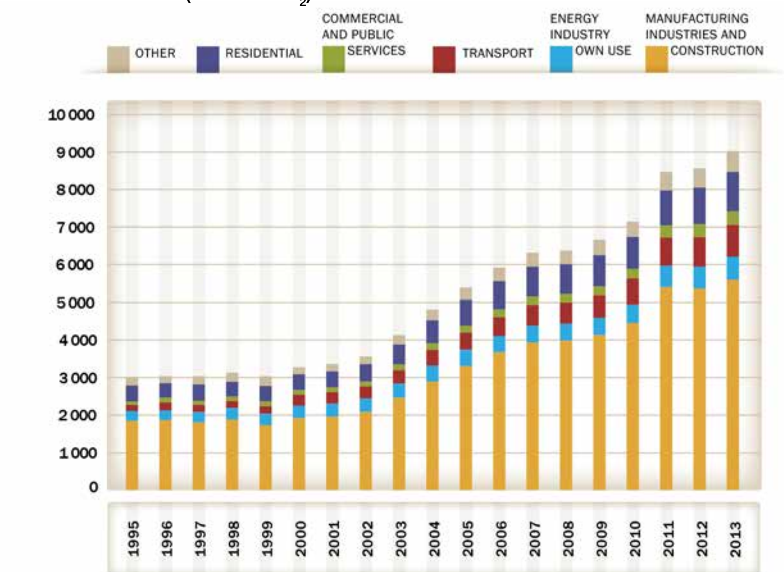
Source: Elaboration by Susdef based on IEA (2015a)

Table 13: **China transport modal share, 2013**

	Passenger PKM	Freight TKM	Total TU
ROAD	45.1%	34.8%	36.2%
AVIATION	22.7%	0.1%	3.1%
NAVIGATION	0.3%	49.6%	43.0%
RAIL	31.9%	15.5%	17.7%

Source: Elaboration by Susdef based on UIC (2015a) and CNBS (2014)

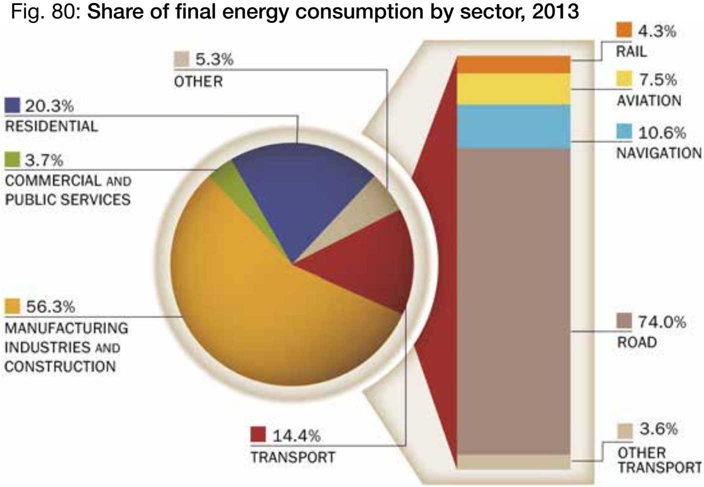
Fig. 79: **Total CO_2 emissions from fuel combustion by sector, 1995-2013 (million tCO_2)**



Note: Electricity and heat emissions are reallocated to the end-use sectors.

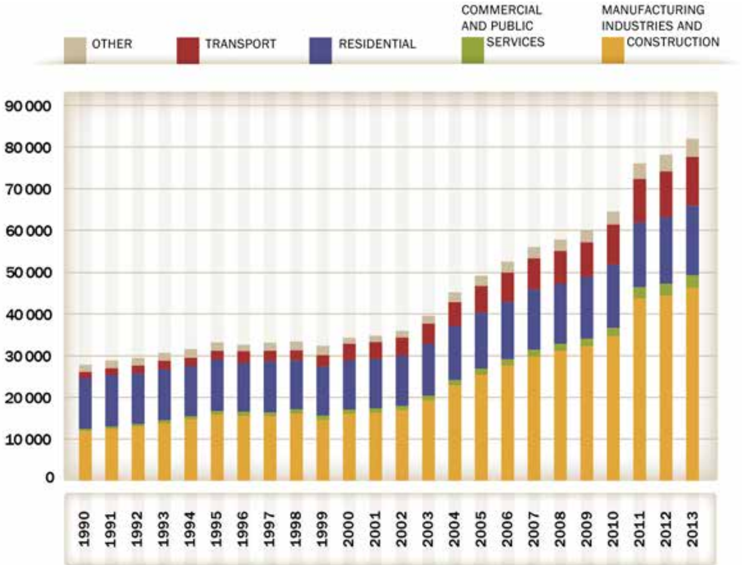
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 80: **Share of final energy consumption by sector, 2013**



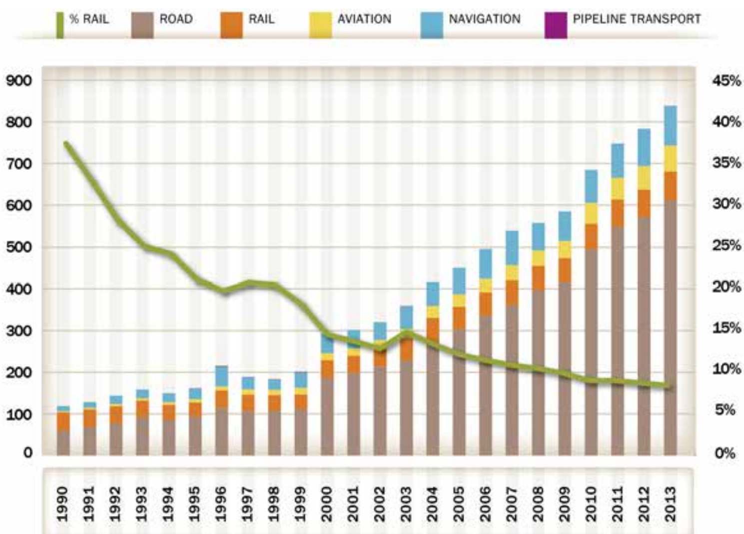
Source: Elaboration by Susdef based on IEA (2015b)

Fig. 81: **Total final energy consumption by sector, 1990-2013 (PJ)**



Source: Elaboration by Susdef based on IEA (2015b)

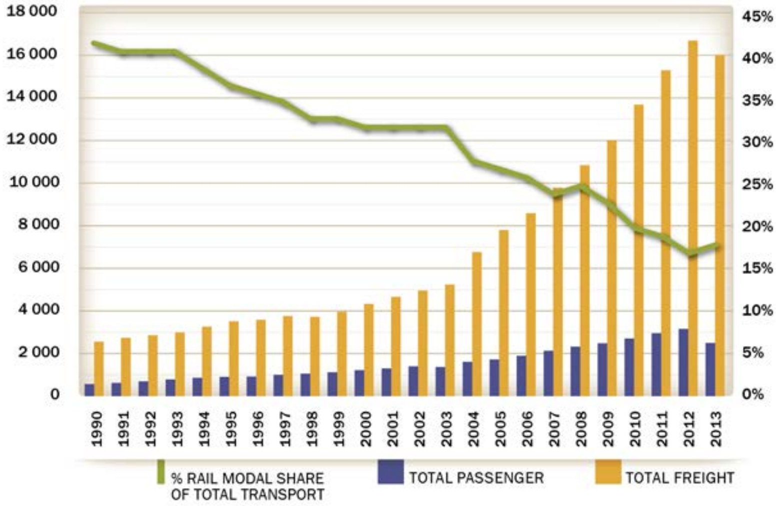
Fig. 82: **Transport sector CO_2 emissions by mode, 1990-2013 (million tCO_2 - left, share of rail over total - right)**



Note: Electricity and heat emissions are reallocated to the end-use sectors. In transport, all the emissions from electricity and heat production are reallocated to rail.

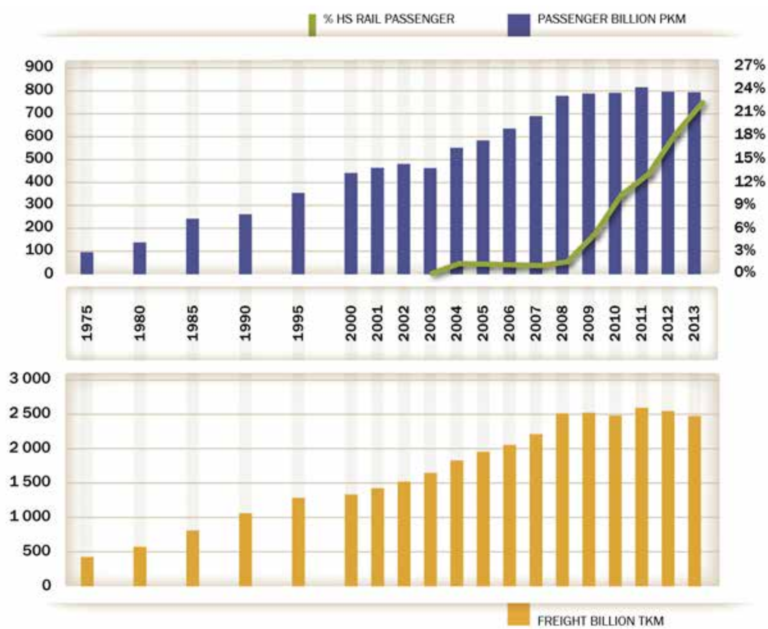
Source: Elaboration by Susdef based on IEA (2015a)

Fig. 83: **Passenger and freight transport activity - all modes, 1990-2013 (billion pkm and tkm – left, share of rail over total – right)**



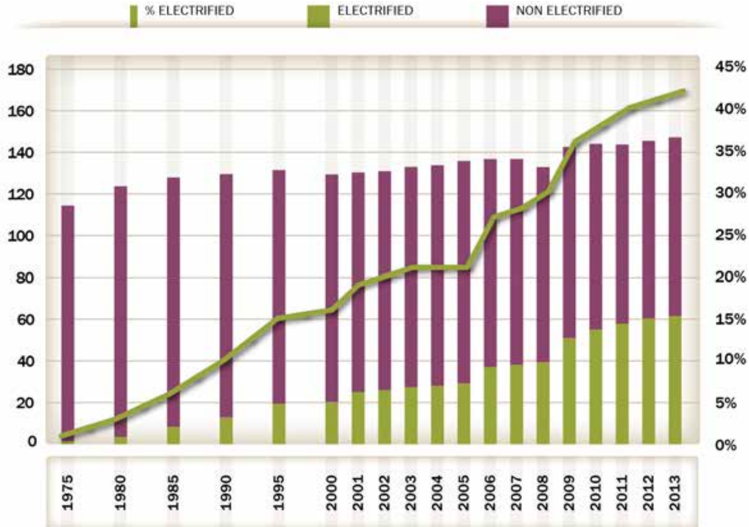
Source: Elaboration by Susdef based on UIC (2015a) and CNBS (2014)

Fig. 84: **Passenger and freight railway activity and High-Speed activity as a share of total passenger railway activity, 1975-2013**



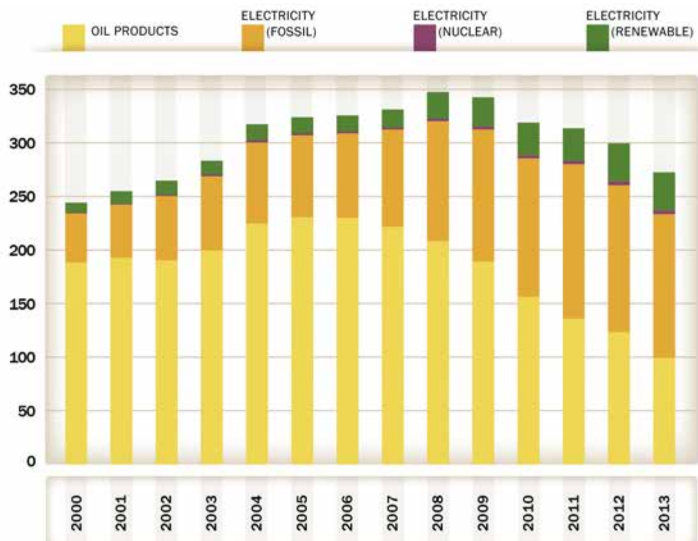
Source: Elaboration by IEA based on UIC (2015a)

Fig. 85: **Length and share of electrified and non-electrified railway tracks, 1975-2013 (thousand km)**



Source: Elaboration by IEA based on UIC (2015a)

Fig. 86: **Railway final energy consumption by fuel, 2000-2013 (PJ)**



Note: See Methodology Notes p. 109

Source: Elaboration by Susdef based on IEA (2016b), IEA (2015b) and UIC (2015a)

Table 14: **China railway energy fuel mix, 2000-2013**

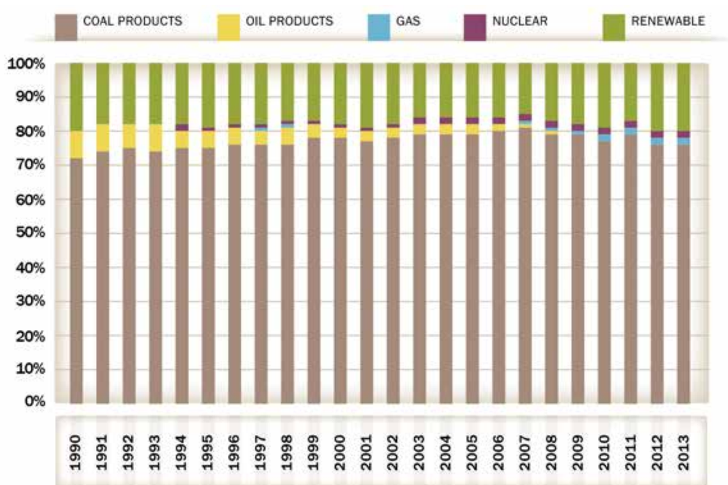
ENERGY MIX BY SOURCE	2000	2013
OIL PRODUCTS	77.1%	36.4%
ELECTRICITY	22.9%	63.6%
of which Fossil	18.8%	49.3%
of which Nuclear	0.3%	1.3%
of which Renewable	3.8%	13.1%

SUMMARY BY SOURCE TYPE	2000	2013
FOSSIL SOURCE	95.9%	85.6%
NUCLEAR	0.3%	1.3%
RENEWABLE	3.8%	13.1%

Note: See Methodology Notes p. 109

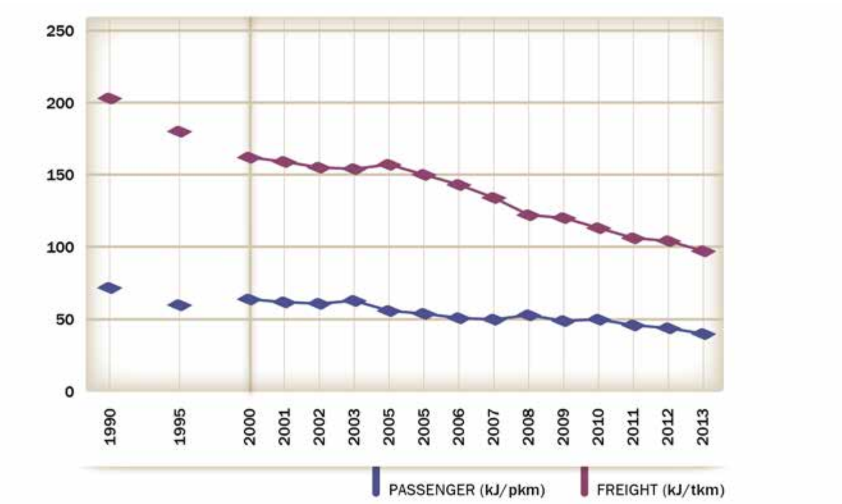
Source: Elaboration by Susdef based on IEA (2016b), IEA (2015b) and UIC (2015a)

Fig. 87: **National electricity production mix evolution, 1990-2013**



Source: IEA (2015b)

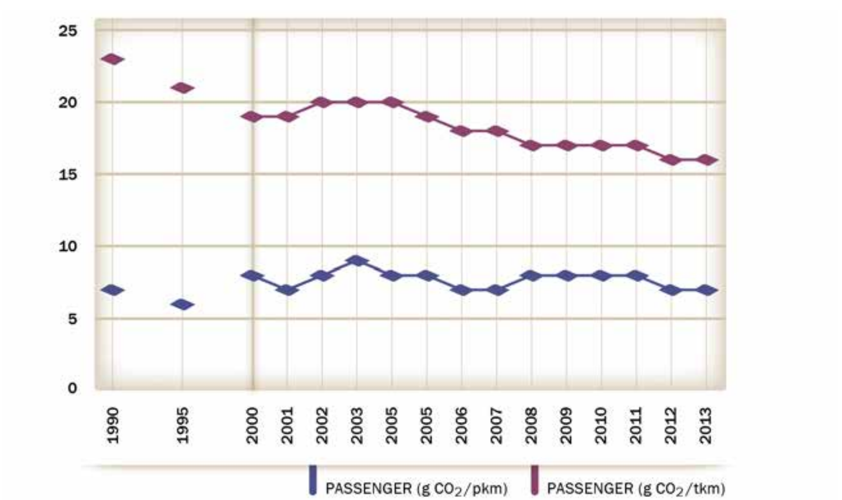
Fig. 88: **Railway specific energy consumption, 1990-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Fig. 89: **Railway specific CO_2 emissions, 1990-2013**



Note: See Methodology Notes p. 109

Source: Elaboration by IEA and Susdef based on IEA (2016b) and UIC (2015a)

Part II:
Focus on Sustainability Targets

FOCUS

Key Facts

- The year 2015 has been marked by the historic Paris Agreement. With its Low Carbon Rail Transport Challenge, UIC has committed to reducing specific final energy consumption per traffic unit (-50% by 2030 and -60% by 2050) and specific average CO_2 emissions from train operations (-50% by 2030 and -75% by 2050), relative to a 1990 baseline. The UIC has also set a modal shift target aiming at achieving a 50% increase of the passenger-km share of rail in total passenger transport by 2030 compared to 2010, and a 100% increase by 2050. In the case of rail freight transport, the target is to achieve the same freight activity (in tonne-km) as the road transport sector by 2030, and a 50% higher activity than the road transport sector by 2050.

- The rates of improvement of rail energy and CO_2 intensity were in line with the 2030 and 2050 targets in 2013 (latest collected data): specific energy consumption has reduced by 37% between 1990 and 2013, and specific CO_2 emissions have reduced by 30% in the same period.

- Before taking global commitments, UIC and the Community of European Railways and Infrastructure Companies (CER) had already ratified targets for the improvement of energy and CO_2 performance in the European railway sector by 2020, 2030 and 2050. Additionally, in order to improve the accounting for CO_2 emissions relative to the procurement of renewable electricity by railway operators, the UIC has adopted in 2014 the “dual reporting approach” (market-based and location-based) recommended by the GHG Protocol Scope[1].

- The UIC-CER set targets for European Railways: 30% specific CO_2 emission reduction by 2020 compared to a 1990 baseline. Additionally, by 2030 the specific CO_2 emissions from train operations have to be reduced by 50% compared to base year 1990. By 2030, the European railways also aim to keep their total CO_2 emission from train operations stable compared to base year 1990, taking into account a projected traffic increase. Targets on energy efficiency have to be achieved by 2030 and 2050, respectively -30% and -50% of specific energy consumption.

[1] GHG Protocol Scope 2 Guidance, carried out by the World Resources Institute, seeks to develop a globally accepted GHG accounting and reporting standard (WRI 2015). The dual reporting approach includes a physical approach and a market approach. Physical approach: using CO_2 emission factors based on the physical flows of electricity between the point of generation and consumption (location based). Market approach: physical emission factors are adjusted to reflect the purchase of renewable energy by consumers, including certificates and guarantees of origin (market based).

- The monitoring of CO_2 emissions carried out by the UIC ESRS (Environmental Strategy Reporting System) highlights that the performance of European railway companies were in line with the above-mentioned targets for 2020, 2030 and 2050. Considering the market-based approach, railways have already achieved the 2020 target for specific CO_2 emissions. The target for total CO_2 emissions were already achieved in 2006 considering both the location-based and market-based approaches; the absolute targets of emissions have to be more prudential since they must take future increases of railways activity into account.

- Comparing CO_2 emissions, energy consumptions and corresponding targets with the estimated ETP 2DS trends emerges as the UIC target are more conservative also in this case. UIC targets were set according to expected forecasts of EU members and ETP 2DS are projections for the best case on policies and technologies implementation on mitigation to climate change

- The share of renewable energy used by the European railway sector is higher than the renewable energy share of all European end-use sectors taken together. European railways have already achieved the EU Climate Package target of using 20% renewable energy in 2011by 2020. Electrification and green procurement played a key role in achieving this target.

- In parallel to the targets set for the rail sector as a whole, a number of railway companies are showing initiative by setting their own energy and sustainability goals.

- Railways are currently more energy and CO_2 efficient per traffic unit than most other transport modes. Railways will likely remain among the most sustainable transport modes in 2030, even when sustainability commitments from stakeholders operating in other transport modes are accounted for.

- The Energy Technology Perspectives 2016 publication (IEA, 2016a) suggests that a large increase in the share of high-speed rail in total transport activity is required to achieve the "2-degree scenario" (2DS), as this would reduce the average carbon intensity of long distance passenger transport.

- In the context of the COP21 event held in Paris in 2015, 75% of the World's countries has established strategies and targets to improve the environmental performance of their transport sector within their Intended Nationally Determined Contributions (INDCs). One-fifth of the transport-related INDCs include measures in the railway sector.

The UIC Low Carbon Rail Transport Challenge and the UIC Climate Responsibility Pledge

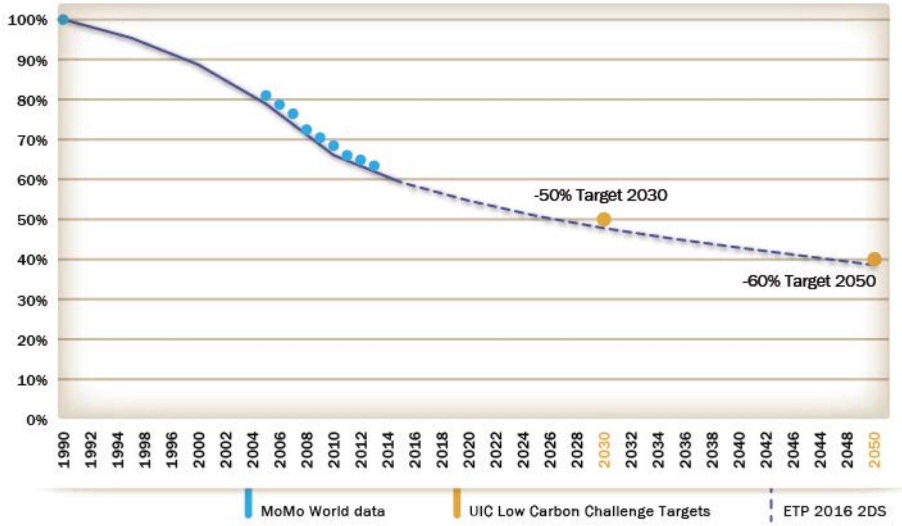
At the UN Climate Summit in September 2014, UIC presented the Low Carbon Rail Transport Challenge. This initiative sets out a vision for the developments of the railway sector at the global level as a sustainable alternative to other modes of transportation that are more carbon intensive such as road transport and aviation. The challenge includes three sets of voluntary targets: to improve rail efficiency, to decarbonise electricity supply, and to achieve a more sustainable balance of transport modes.

UIC is committed to reducing specific final energy consumption per traffic unit (50% by 2030 and 60% by 2050) and specific average CO_2 emissions per traffic units from train operations (50% by 2030 and 75% by 2050), all relative to a 1990 baseline. In order to reach these goals, railway operators are investing in electrifying trains, improving load factors, procuring more efficient rolling stock, developing more efficient energy and traffic management systems, and promoting efficient driving.

In 2015, UIC has also launched the Modal Shift Challenge calling for investments that encourage a shifting towards rail transport and away from more carbon intensive transport options (UN, 2014b). The goal of this action is to achieve a 50% increase in the share of rail in passenger transport (measured in passenger-km) by 2030 compared to 2010, followed by a 100% increase by 2050. For land-based freight transport, the target is to achieve the same level of rail activity (in tonne-km) as the road transport sector (mainly represented by trucks) by 2030, achieving a share that is 50% greater than 2010 levels by 2050.

One key component of the Modal Shift Challenge is the Railway Climate Responsibility Pledge, which sets out industry actions to complement the targets set for railways world-wide. During the 2015 Train to Paris event, a programme focused on raising awareness to the role rail can play in the overcoming the climate challenge, this pledge was presented to high level representatives of the United Nations. The Climate Responsibility pledge was well received, having been signed by more than 60 UIC members, representing the majority of global rail activity.

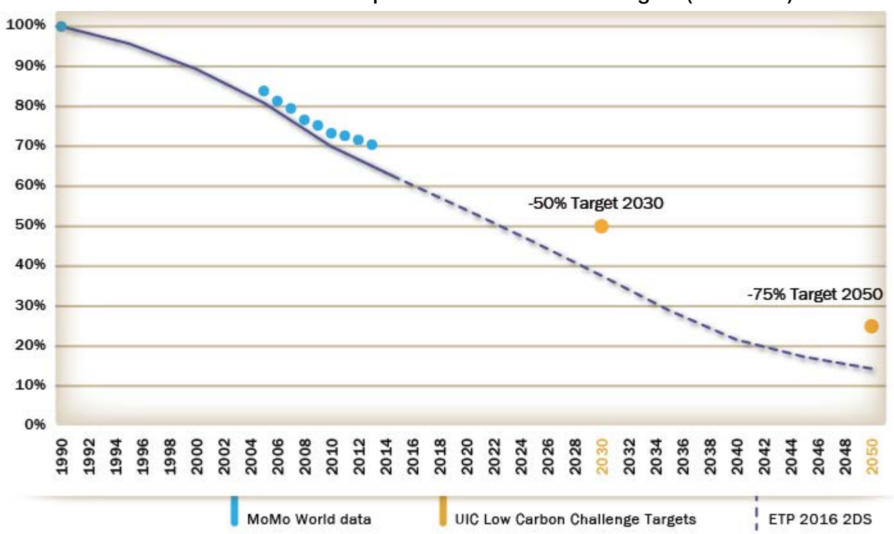
Fig. 90: **World specific rail energy consumption evolution per traffic unit (TU) between 1990-2013 compared to 2030 and 2050 targets (1990=100)**



Source: Elaboration by SUSDEF based on IEA (2016b), UIC (2015a) and UIC (2015d)

Note: See Methodology Notes p. 109; the IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C.

Fig. 91: **World specific rail CO_2 emissions evolution per traffic unit (TU) between 1990 and 2013 compared to 2030 and 2050 targets (1990=100)**



Source: Elaboration by SUSDEF based on IEA (2016b), UIC (2015a) and UIC (2015d)

Note: See Methodology Notes p. 109; the IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C.

INTERNATIONAL UNION OF RAILWAYS

TRAIN to Paris 2015

UIC Railway Climate Responsability Pledge

On the low carbon track

The worldwide railway community is aware that a shift towards sustainable transport is essential to achieve the internationally agreed goal of limiting climate change to a rise in average global temperature of no more than 2 degrees Celsius.

The rail sector is the most emissions efficient transport mode, but as a major transport mode we acknowledge our responsibility and that further improvement is needed. This pledge sets out ambitious but achievable goals for the sectors contribution towards the solution to climate change.

As a member of the worldwide community of railway operators and infrastructure managers, I commit to take a leading role in the actions to prevent climate change, by reducing my company's carbon footprint and supporting a shift towards a more sustainable balance of transport modes.

In order to achieve this, I pledge to:

1. *reduce my company's specific energy consumption and CO_2 emission*, and through this contribute to the UIC "Low Carbon Rail Transport Challenge" and its global 2030/2050 targets, presented in 2014 at the UN Climate Summit;

2. *stimulate modal shift to rail in national and international markets,* by working in partnership with key stakeholders;

3. *actively communicate climate friendly initiatives undertaken by my company during the year 2016 and beyond*, in order to raise awareness, acceptance and recognition of the role of sustainable transport as a part of the solution to climate change;

4. *report data on my company's specific energy consumption and CO_2 emissions to UIC on a regular basis*, in order to promote and demonstrate the continuous improvement of railway sector at international level.

....

Place, date

....

Signature

....

First name, family name, title of signee

Case Study

Reducing the carbon footprint in the Dutch railway sector

Achieving the ambitious targets set out by the Low Carbon Rail Transport Challenge requires the commitment of each railway operator to improve its energy efficiency, reducing its environmental impact by mitigating their CO_2 emissions.

In 2015 the Dutch Minister of Transport and the Dutch National Railways took a decisive first step by signing into law CO_2-vision 2050, a plan which sets targets aimed at reducing the company's carbon footprint (NS, 2015).

This plan is in line with the following UIC Challenge Targets:

- Full CO_2 neutral railway sector (CO_2 emissions from energy and materials) by 2050
- Improve energy efficiency by 35% by 2030 and 40% by 2050 compared to 2013
- Reduce emissions by supporting modal shift from other modes of transport to rail.

Signature of the Dutch Carbon Vision 2050 for railways by representatives of the Dutch Government, ProRail and NS (photo © Dutch Government)

The UIC-CER Commitment at European Level

The EU emphasized the importance of setting medium and long term targets for the reduction of CO_2 emissions (EU, 2007). The railway sector is in a position of competitive advantage in regards to carbon intensity compared to other transport modes. Nonetheless, the sector will continue its efforts of reducing CO_2 emissions in the future.

In 2008 the Community of European Railway and Infrastructure Companies (CER) agreed on a CO_2 reduction target for the European railway sector. The approved targets were a 30% specific CO_2 emission reduction by 2020 compared to a 1990 baseline and a 50% reduction of specific CO_2 emissions from train operations by 2030 compared to 1990. Additionally, the European railways aim to keep their total CO_2 emission from train operations at the level of 1990, counterbalancing the effect of projected traffic increase (UIC and CER, 2010).

The UIC Environmental Strategy Reporting System (ESRS) has been created as a comprehensive instrument which allows the overall procedure of data collection, analysis, reporting, tracking of indicators, and data sharing to be structured in a clear and transparent way. Today, it is the main instrument used to monitor the environmental performance of the European railway sector in achieving the four target goals set by the UIC/CER Sustainable Mobility Strategy 2030 (UIC, 2015c).

Table 15: **UIC-CER Railway sector targets overview at European level**

	TARGET	BASELINE	HORIZON
1. CLIMATE PROTECTION	-40% specific CO_2 emissions (per pkm and tkm) -50% specific CO_2 emissions (per pkm and tkm) Carbon-free train operations	1990 1990 -	2020 2030 2050
2. ENERGY EFFICIENCY	-30% specific energy consumption (per pkm and tkm) -50% specific energy consumption (per pkm and tkm)	1990 1990	2030 2050
3. EXHAUST EMISSIONS	-40% Total particulate matter and nitrogen oxides Zero emissions of particulate matter and nitrogen oxides	2005 -	2030 2050
4. NOISE AND VIBRATIONS	No Longer a problem for the railways	-	2050

Source: UIC (2015c)

The next step for increasing the reliability of the UIC Environment Strategy Reporting System (ESRS) is to define a transparent methodology for monitoring the purchase of green electricity (electricity produced void of net CO_2 emissions) by railway companies. Operating electrified rolling stock on green electricity is one of the key factors in reducing CO_2 emissions in the rail sector. The Zero Carbon Project was developed in this context and allows the reporting of Guarantees of Origin (GOs) according to the GHG Protocol guidelines within the UIC Environmental Strategy, to reduce CO_2 emissions with targets for 2030 and a vision for carbon-free rail by 2050.

Following the UIC Zero-Carbon Project, the UIC ESRS adopted the Dual Reporting Approach a methodology employed to most accurately represent both the movement and purchase of green electricity.

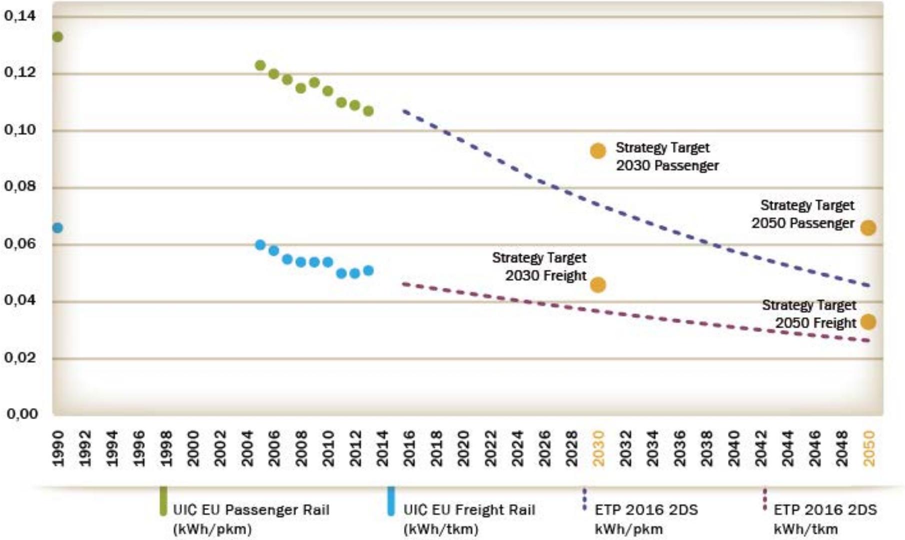
In this framework, CO_2 reporting is conducted according to two complementary approaches:

• The physical approach: using CO_2 emission factors based on the physical flows of electricity between the point of generation and consumption (location based).

• The market approach: physical emission factors are adjusted to reflect the purchase of renewable energy by consumers, including certificates and guarantees of origin (market based).

This approach follows the Greenhouse Gas (GHG) Protocol (Scope 2 Guidance) developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (WRI, 2015).

Fig. 92: **UIC-Europe Railways specific energy consumption evolution (passenger and freight services) between 1990 and, 2013, compared to UIC-CER 2030 and 2050 targets at EU level**



Source: Elaboration by SUSDEF based on UIC (2015b) and IEA (2016b)

Note: See Methodology Notes p. 109; the IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C.

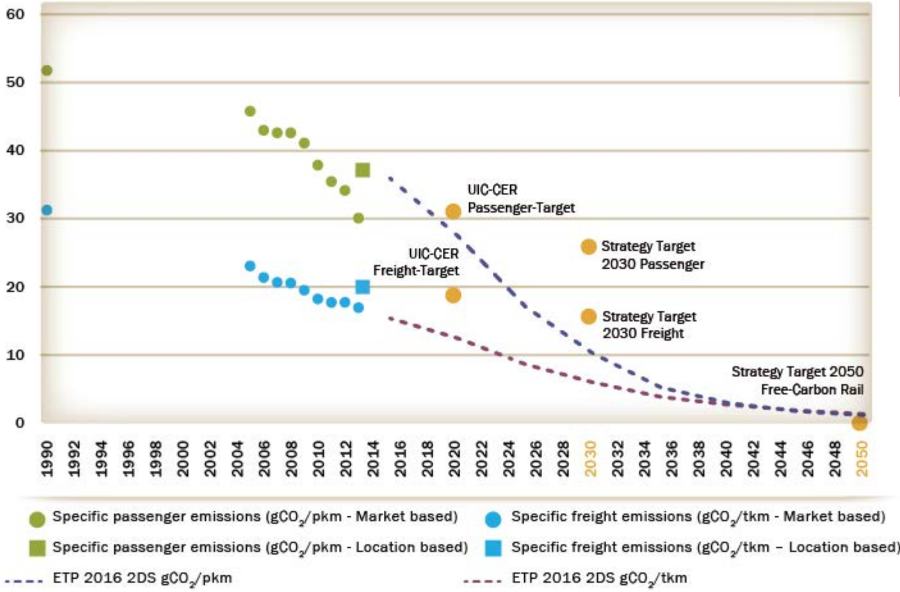
Table 16: **Environmental Strategy Reporting System (ESRS) data monitoring dashboard - Specific passenger and freight energy consumption**

	Specific passenger energy consumption	Specific freight energy consumption
SECTOR TARGET 2030 (BASE YEAR: 1990)	-30%	-30%
SECTOR TARGET 2050 (BASE YEAR: 1990)	-50%	-50%
LINEAR EXPECTED PERFORMANCE 1990-2013 FOR THE 2030 SECTOR TARGET	-17%	-17%
REAL PERFORMANCE 1990-2013	-20%	-22%

Source: UIC (2015b)

Note: the linear expected performance is the overall performance that was necessary to achieve between 1990 and 2013 in order to be on track to achieving the 2030 target, when assuming a linear improvement between 1990 and the 2030 target. This indicator is used for comparison purposes with the real performance number, showing historical improvements.

Fig. 93: **UIC-Europe Railways specific CO_2 emissions evolution (passenger and freight services) between 1990 and 2013, compared to UIC-CER 2030 and 2050 targets at EU level (including dual reporting)**



Source: Elaboration by SUSDEF based on UIC (2015b) and IEA (2016b)

Note: See Methodology Notes p. 109; the IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C.

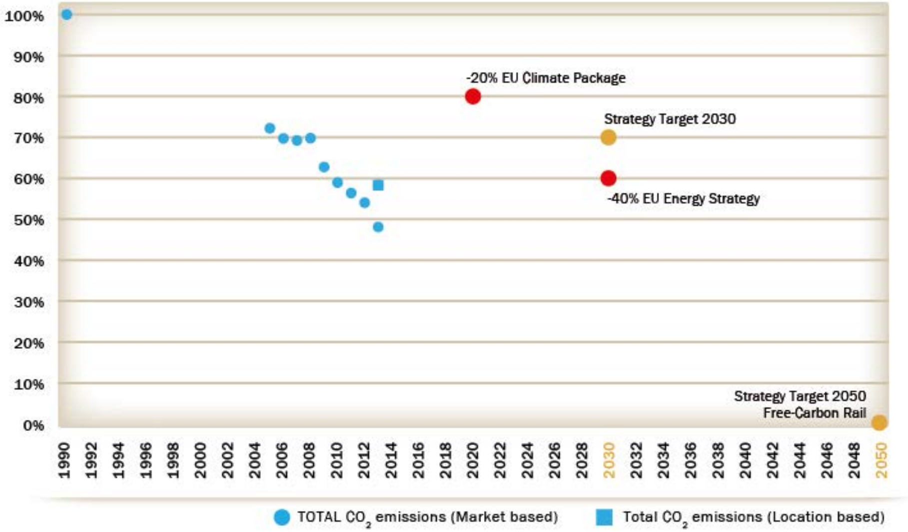
Table 17: **Environmental Strategy Reporting System (ESRS) data monitoring dashboard - Specific passenger and freight CO_2 emissions**

	Specific passenger CO_2 emissions	Specific freight CO_2 emissions
SECTOR TARGET 2020 (BASE YEAR: 1990)	-40%	-40%
SECTOR TARGET 2030 (BASE YEAR: 1990)	-50%	-50%
SECTOR TARGET 2050	Free-Carbon	Free-Carbon
LINEAR EXPECTED PERFORMANCE 1990-2013 FOR THE 2030 SECTOR TARGET	-31%	-31%
REAL PERFORMANCE 1 990-2013 (MARKET-BASED)	-42%	-45%
REAL PERFORMANCE 1990-2013 (LOCATION-BASED)	-29%	-35%

Source: UIC (2015b)

Note: the linear expected performance is the overall performance that was necessary to achieve between 1990 and 2013 in order to be on track to achieving the 2030 target, when assuming a linear improvement between 1990 and the 2030 target. This indicator is used for comparison purposes with the real performance number, showing historical improvements.

Fig. 94: **UIC-Europe Railways total CO_2 emissions evolution (including dual reporting) between 1990 and 2013 compared to EU targets and UIC Strategy 2030 and 2050 target (1990=100)**



Source: Elaboration by SUSDEF based on UIC (2015b), EU (2008) and EU (2014)

Note: The EU Climate Package and the EU Energy Strategy set targets for the transport sector as a whole. This includes the railway sector.

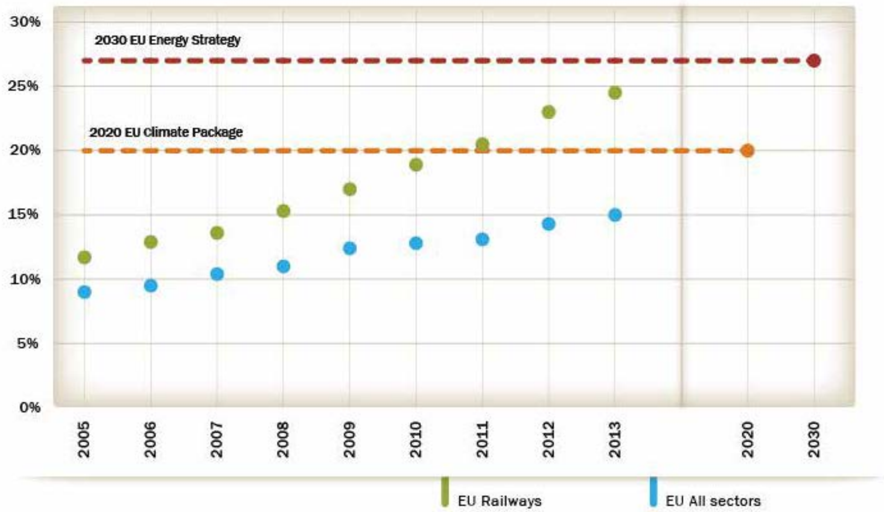
Table 18: **Environmental Strategy Reporting System (ESRS) data monitoring dashboard - Total CO_2 emissions**

	Total CO_2 Emissions
SECTOR TARGET 2030 (BASE YEAR: 1990)	-30%
SECTOR TARGET 2050 (BASE YEAR: 1990)	Free-Carbon
LINEAR EXPECTED PERFORMANCE 1990-2013 FOR THE 2030 SECTOR TARGET	-17%
REAL PERFORMANCE 1990-2013 (Market-based)	-52%
REAL PERFORMANCE 1990-2013 (Location-based)	-42%

Source: UIC (2015b)

Note: the linear expected performance is the overall performance that was necessary to achieve between 1990 and 2013 in order to be on track to achieving the 2030 target, when assuming a linear improvement between 1990 and the 2030 target. This indicator is used for comparison purposes with the real performance number, showing historical improvements.

Fig. 95: **Share of renewable energy consumption of all European sectors and the EU railway sector (according to the market based approach) compared to EU targets**



Source: Elaboration by SUSDEF based on UIC (2015b) and EUROSTAT (2016)

Note: EU All sectors describes the trend of the share of renewable energy in the EU's gross final energy consumption. According to the EC 2009/28/EC directive, gross final energy consumption refers to the energy commodities delivered for energy purposes to industry, transport, households, services including public services, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution and transmission. EU Railways describes the trend of the share of renewable energy (according to the market-based approach) in the European Railway sector.

Targets set by rail companies

Table. 19: **Examples of targets set by rail companies**

COMPANIES	CO_2 TARGETS	ENERGY TARGETS
ATOC NETWORK RAIL Country: United-Kingdom Source: ATOC (2015)	Reduction of carbon emissions by 34% by 2020 and by 80% by 2050, both from 1990 levels (in line with the UK Government targets).	
DEUTSCHE BAHN Country: Germany Source: DB (2016)	By 2020, reduction of specific CO_2 emissions from rail, road, air and ocean transportation by 30% compared to 2006 levels. By 2050, rail transport completely CO_2-free.	Increase of renewable energy sources (increase to 45% until 2020).
INDIAN RAILWAYS Country: India Source: UNDP (2011)	Saving of 3.33 million tonnes of CO_2 by 2020 (80% over the period 2011/12-2020/21).	Saving of 4.05 billion kWh by 2020.
JR-EAST Country: Japan Source: JR-East (2014)	Halving of CO_2 emissions from its railway business by FY 2030 compared to FY 1990. CO_2 emissions: -30% by 2021 relative to 1991.	Energy Consumption: -8% by 2021 relative to 2011.
JR-WEST Country: Japan Source: JR-West (2016)		Energy consumption rate (MJ/Rolling-stock km) -3% compared to FY 2011. 83% Energy-saving railcars as a percentage of total railcars in FY 2018.
KORAIL Country: South Korea Source: KORAIL (2015)	GHG mid-term reduction goals: -8% by 2019 from 2015 levels.	
NS Group Country: Netherlands Source: NS (2015)	Full CO_2 neutral railway sector (CO_2 emissions from energy and materials) by 2050.	Improve energy efficiency by 35% by 2030 and 40% by 2050 compared to 2013
NSB Country: Norway Source: NSB (2015)		Reduction of power consumption by 15% from 2013 to 2017.
Renfe Country: Spain Source: Renfe (2015)	Less than 20 g of CO_2 per traffic unit (TU).	

COMPANIES	CO_2 TARGETS	ENERGY TARGETS
RZD Country: Russia Source: RZD (2014)	Reduction of the negative environmental impact (CO_2 emissions) by 7% in 2017 and by 15% in 2030 compared to 2012 (optimistic scenario).	
SNCB Country: Belgium Source: SNCB (2012)		Use 1% less traction-energy per passenger-km annually between 2010 and 2020.
SNCF Country: France Source: SNCF (2016)	Cutting GHG emissions by 20% between 2014 and 2025.	Traction: reduce electricity and diesel fuel consumption by 20% between 2012 and 2022. Buildings: reduce electricity, home heating oil and natural gas consumption by 20% between 2012 and 2020.
THALYS Country: International HS Source: THALYS (2015)	Reduction of CO_2 emissions by 40% by 2020 compared to 2008 levels.	
VIA RAIL CANADA Country: Canada Source: VIA RAIL CANADA (2015)	Reduce GHG emissions by 20% by 2020 and 30% by 2030 compared to 2005 levels.	

Targets set by rail, road, maritime, and aviation transport sectors

This section evaluates CO_2 reduction targets for different modes of transport. The characteristics and types of targets are different in nature and, in most cases, they cannot be directly compared.

• Existing regulations on the fuel economy of passenger cars, light commercial vehicles, and trucks take into account the average performance of new vehicle registrations. Currently, the vehicle's CO_2 emissions and energy consumption are determined through laboratory tests relying on a standardized driving cycle and the use of metrics that relate energy consumption or CO_2 emissions to vehicle km. Targets aiming to reduce CO_2 emissions/km for new vehicle registrations have been adopted in most car markets, affecting roughly three vehicles sold out of four. Compared to 2014, the US and the EU require annual reductions of specific CO_2 emissions/km of passenger cars of 4.1% and 3.8%, respectively, until 2025 and 2021 (ICCT, 2016; EU, 2014b; EEA, 2016). The annual improvement rate required in China to meet 2020 regulatory targets since the 2014 baseline equals 5.9% per year (ICCT, 2016).

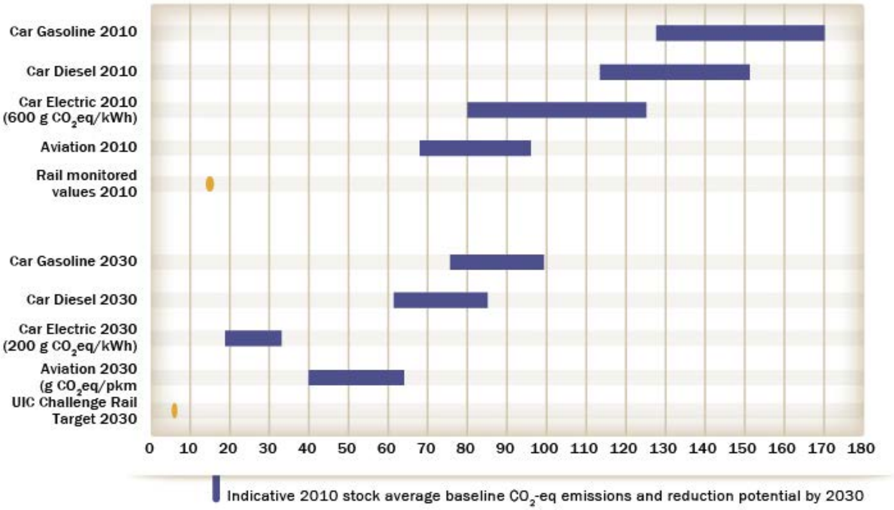
• Regulations developed in maritime transport (via the Energy Efficiency Design Index implemented by the International Maritime Organization) target new vehicle registrations since 2015, requiring a minimum energy efficiency level for different ship type and size segments. This uses a metric that accounts for changes in carrying capacity. The 30% improvement required for new ships by 2025 (against the baseline of ships built between 2000 and 2010), compared to the 10% needed in 2015, translates into an annual energy efficiency improvement of around 2.5% for new ships entering the fleet between 2015 and 2025 (IMO, 2011).

• The railway sector set CO_2 emission mitigation targets focusing on the energy and carbon intensity of their operational performance (and in some company cases to their rolling vehicle stock rather than new registrations). The metric adopted in this case links energy use or GHG emissions with activity parameters that also embed loads or occupancy rates (e.g. transport unit, passenger km and tonne km, rather than vehicle km). The global UIC rail target set a reduction of specific CO_2 emissions of 75% between 1990 and 2050 (UIC, 2014). Given the improvements achieved to the latest available year (2013), this means that specific CO_2 emissions per transport unit need to decline by 1.2% per year until 2050. In addition, UIC and CER set two targets for the European sector: one for the passenger rail sector and one for the freight rail sector, requiring each sector to reduce its specific CO_2 emissions (per pkm and tkm, respectively) with 50% between 1990 and 2030 (UIC and CER, 2010). For the passenger sector, improvements achieved until 2013 require a rate of reduction for specific CO_2 emissions between 2013 and 2030 of 1.4%. For freight rail, the 2030 target was already very close to be achieved in 2013.

• The aviation sector set its own aspirational goals looking directly at the GHG emission envelope of the sector: stabilization of GHG emissions by 2020 (or carbon-neutral growth), and halving by 2050 compared to 2005 (UN, 2014a and ATAG, 2016). Several contributions are expected to be needed to meet these goals: energy efficiency improvements derived from technology developments, lower carbon intensity of energy carriers attributed to to fuel switching, energy savings derived from operational improvements (such as the increase in load factors), and GHG emission reductions derived from carbon offsets in other sectors thanks to market based mechanisms. In addition to this, the International Civil Aviation Organization (ICAO) has also introduced an aspirational goal to improve energy efficiency by 2% per year until 2050, specifically looking at operational and technical improvements (ICAO, 2010 and ICAO, 2013). The metric for this target is relating to the volume of fuel used per revenue tonne km. The aviation sector is also developing a regulation imposing binding energy efficiency and CO_2 reduction targets for the aviation sector.

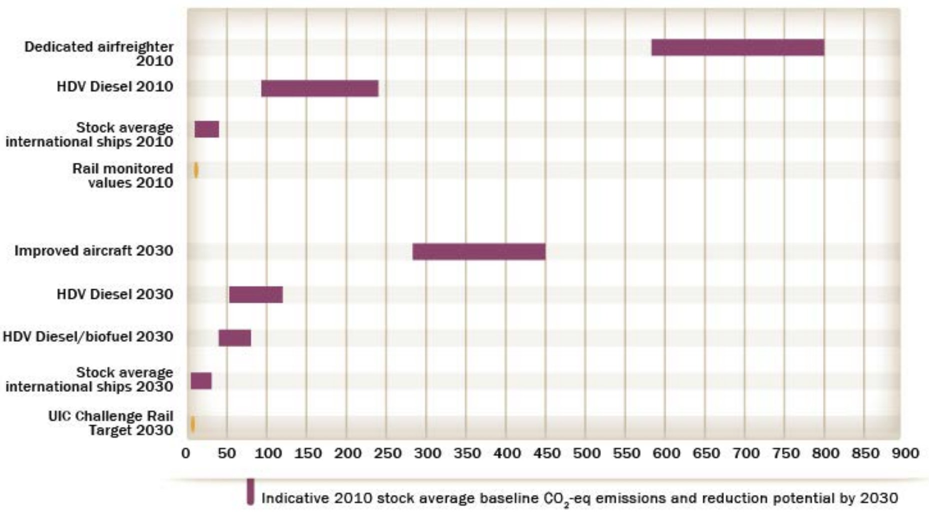
Figures 96 and 97 show the estimated CO_2 emissions for all modes of transport by 2030 compared to historical figures from, 2010, suggesting that rail will remain the transport mode with the lowest carbon intensity in 2030.

Fig. 96: **Comparison between UIC Low Carbon Rail Transport Challenge Targets and CO_2-eq mitigation potential by 2030 – Passenger (gCO_2-eq/pkm)**



Source: Elaboration by SUSDEF based on IPCC (2014) and IEA (2016b)

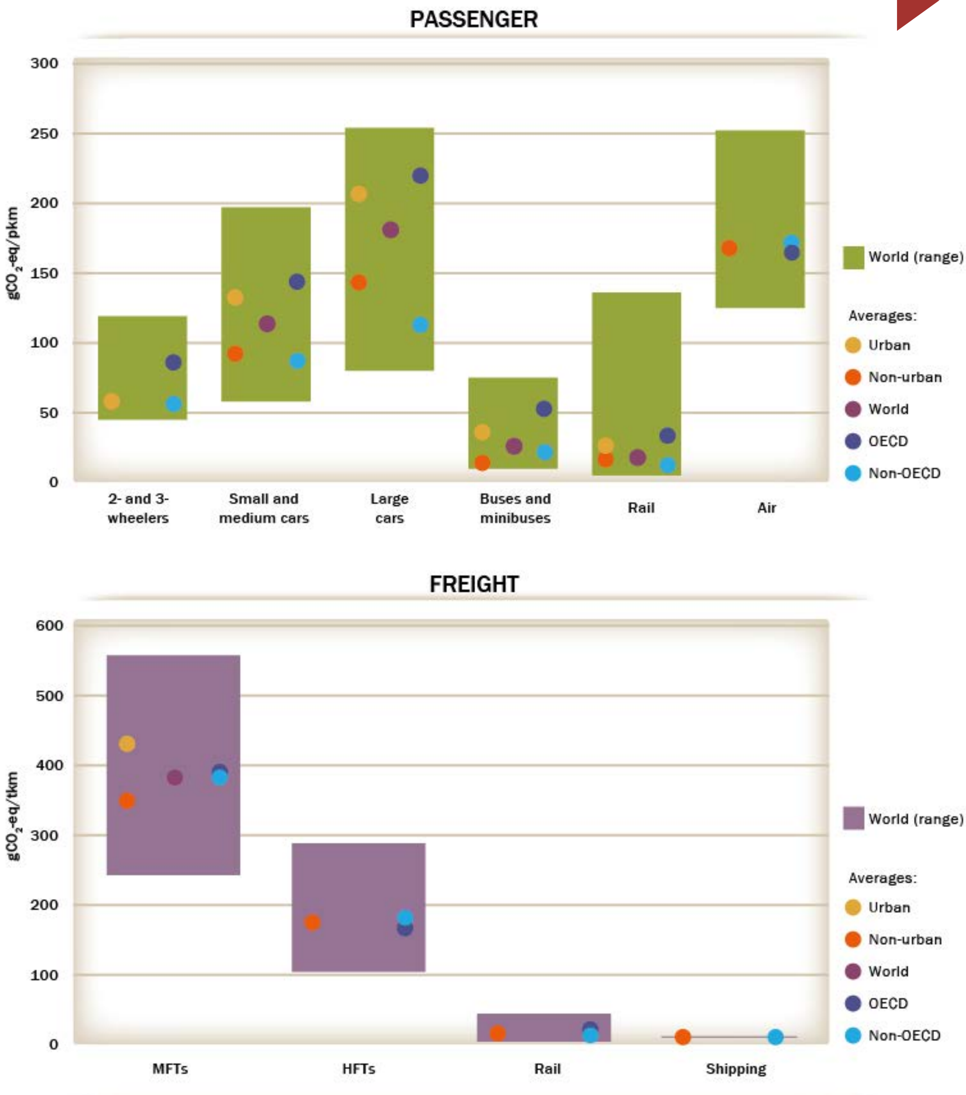
Fig. 97: **Comparison between UIC Low Carbon Rail Transport Challenge Targets and CO_2-eq mitigation potential by 2030 – Freight (gCO_2-eq/tkm)**



Source: Elaboration by SUSDEF based on IPCC (2014) and IEA (2016b)

Note: With the exception of the values relating to the railway sector, the numbers have been derived from IPCC (2014). For the calculation of electric car emissions, the IPCC considers the carbon intensity of the national grid. For the railway sector the rail monitored values for 2010 were derived from the IEA Mobility Model, and the 2030 target refers to the UIC Rail Low Carbon Transport Challenge.

Fig. 98: **Current Well-to-Wheel GHG intensities of passenger and freight transport activity, 2015**



Source: IEA (2016a)

Focus on regulatory policies targeting passenger cars and light commercial vehicles

Fuel economy standards play a significant role in national fuel efficiency policies. When properly implemented, fuel efficiency legislation can effectively reduce the energy use and GHG emissions of road transport vehicles, having even broader impacts in countries with booming car and truck markets. Long lasting and consistent fuel economy standards have the capacity to have sizeable impacts on the reduction of fossil energy use, even in the presence of rebound effects, such as the increase of the average mileage due to lower costs per km travelled. In the last decade, several governments have established or proposed efficiency standards for light-duty vehicles, including passenger cars, light trucks (a definition used in North America for large passenger cars, such as Sport Utility Vehicles and pick-ups) and light commercial vehicles. Fuel economy standards for cars are now in place for about three quarters of new registrations of passenger cars (GFEI, 2015) and nearly half of those of new trucks (IEA, 2016b).

Selected examples of regulatory developments, focusing on the major global economies, are provided below (GFEI, 2016):

• Fuel economy regulations for passenger cars were first introduced in China in 2005. During Phase I and Phase II, individual models were required to meet specific thresholds, which were differentiated on the basis of vehicle weight. Corporate average fuel consumption targets were established with the introduction of Phase III (2012-15). Phase IV, which took effect on January 1st 2016, targets an average specific fuel consumption for new car sales of 5.0 L/100 km by 2020 (based on the NEDC) (TransportPolicy, 2016).

• Voluntary CO_2 emission standards were first introduced in the European Union in 1998, and they became mandatory in 2009. The 2015 target of 130 g CO_2/km for passenger cars was met in advance in the case of France (EEA, 2015). By 2021, CO_2 emissions of passenger cars should reach 95 g CO_2/km (based on NEDC), and those of LCVs are required to attain 147 g CO_2/km (based on NEDC) (TransportPolicy, 2016).

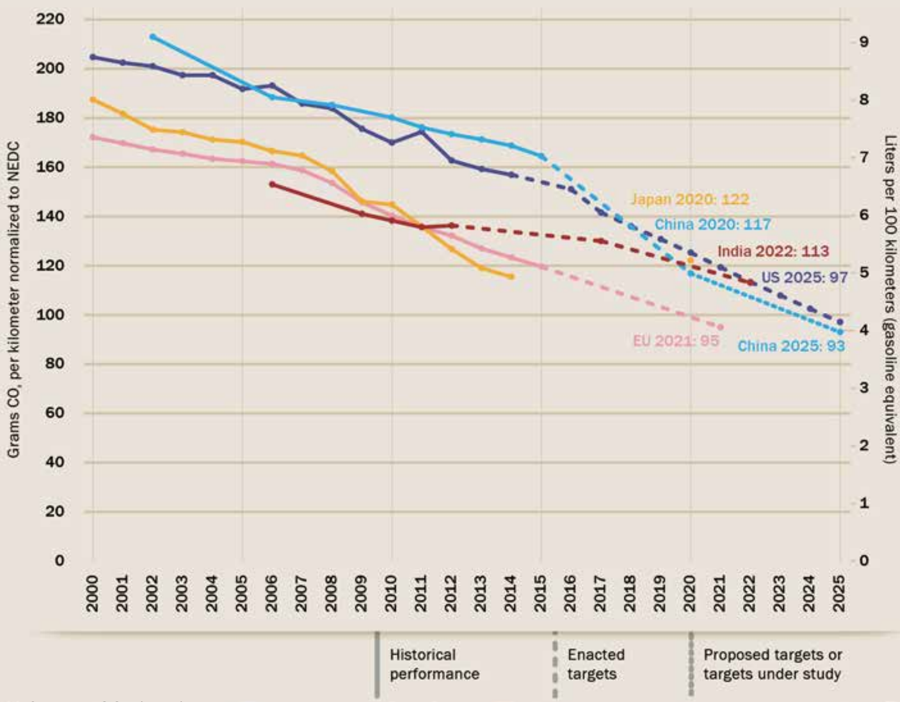
• In January 2014, the Indian government enacted a regulation on the CO_2 intensity of new cars taking effect in April 2016 (TransportPolicy, 2016). The regulation establishes a fleet target of 130 g CO_2/km for 2016, which will go down to 113 g CO_2/km in 2021 (based on NEDC) (TransportPolicy, 2016).

• Fuel economy standards have a long history in Japan. The first regulation was put in place in 1979, and applied first to 1985 vehicles. The Top Runner Program, introduced in 1999, required all vehicles in a given weight class to exceed the fuel economy of the best performing model within three to ten years (TransportPolicy, 2016). Fuel economy labelling has also been mandatory since the year 2000 (ICCT, 2015). Japanese fuel economy standards have resulted in ambitious improvement targets in the past. Recent regulatory targets (for 2020) are less aggressive than in Europe, despite the fact that average national new sales fuel economies in Europe and Japan in 2013 were similar in magnitude.

• Fuel economy regulations were first established in the United States 1970s. The Corporate Average Fuel Economy (CAFE) standards were introduced in 1975. Fuel economy labelling of new cars was introduced as early as 1978 (ICCT, 2015). Even if the United States pioneered their introduction, the historical evolution of regulatory limits underwent distinct phases, including decades (late 1980s, 1990s and early 2000s) of stagnation. This resulted in deteriorating fuel economy due to a market shift towards larger vehicles. In 2009, the stringency of fuel economy improvements for models entering the market between 2012 and 2016 was strengthened considerably. Compared to 2009, by 2016 average CO_2 emissions per km must be reduced by 26% (of about 4.2% per year). Targets were extended to 2025 and will require a 35% reduction of the average fuel use per km from 2016 (TransportPolicy, 2016).

Figure 99 provides a summary of emission trajectories and proposed regulatory targets for passenger cars in selected countries and global regions.

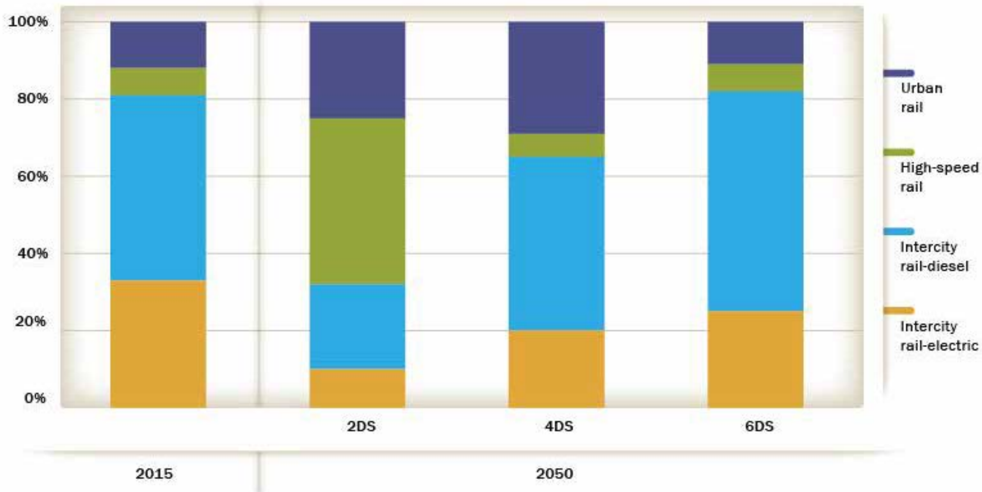
Fig. 99: **Fuel consumption and CO_2 reduction (g CO_2/vkm) targets for passenger cars**



Source: ICCT (2016)

Current performance and planned evolution in railway activity shares, in specific energy consumptions and CO_2 emissions by sector, according to IEA ETP 2016

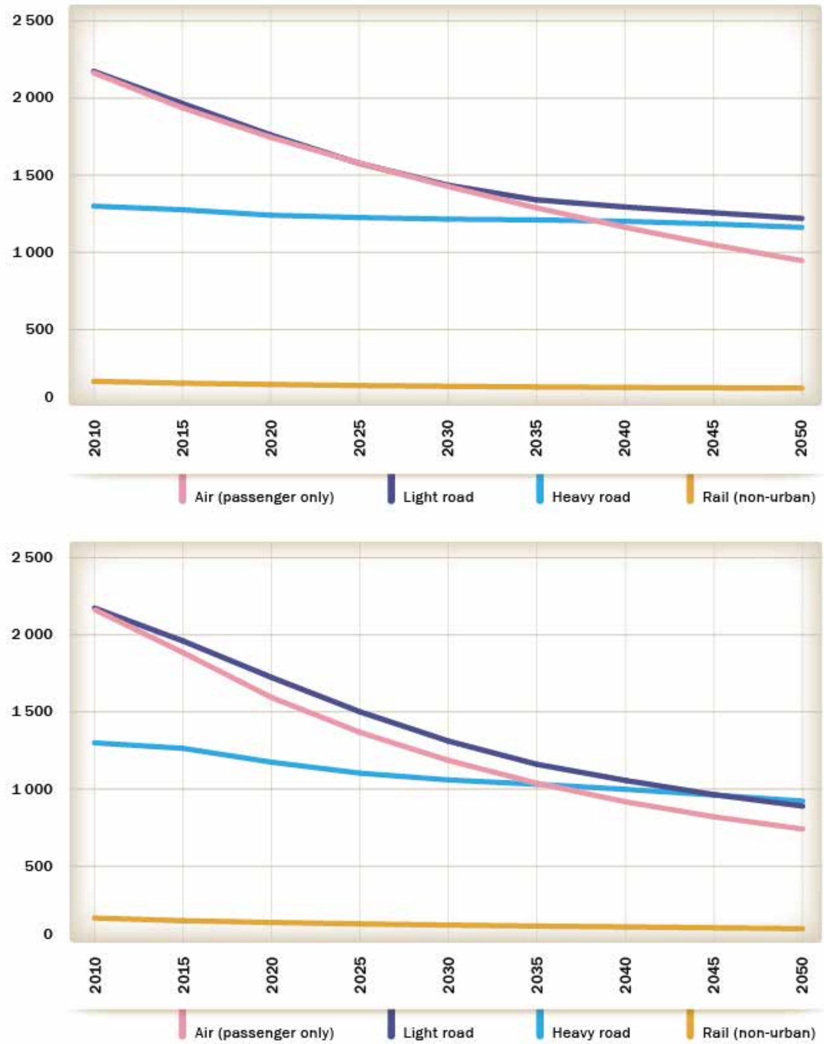
Fig. 100: **Shares of passenger rail activity by scenario**



Source: IEA (2016b)

Note: The IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C. The IEA 4 Degree Scenario takes into account recent pledges by countries to limit emissions and improve energy efficiency, which help limit the long-term temperature increase to 4°C. The 6DS is largely an extension of current trend. In this scenario the average global temperature rise above pre-industrial levels is projected to reach almost 5.5°C in the long term and almost 4°C by the end of this century.

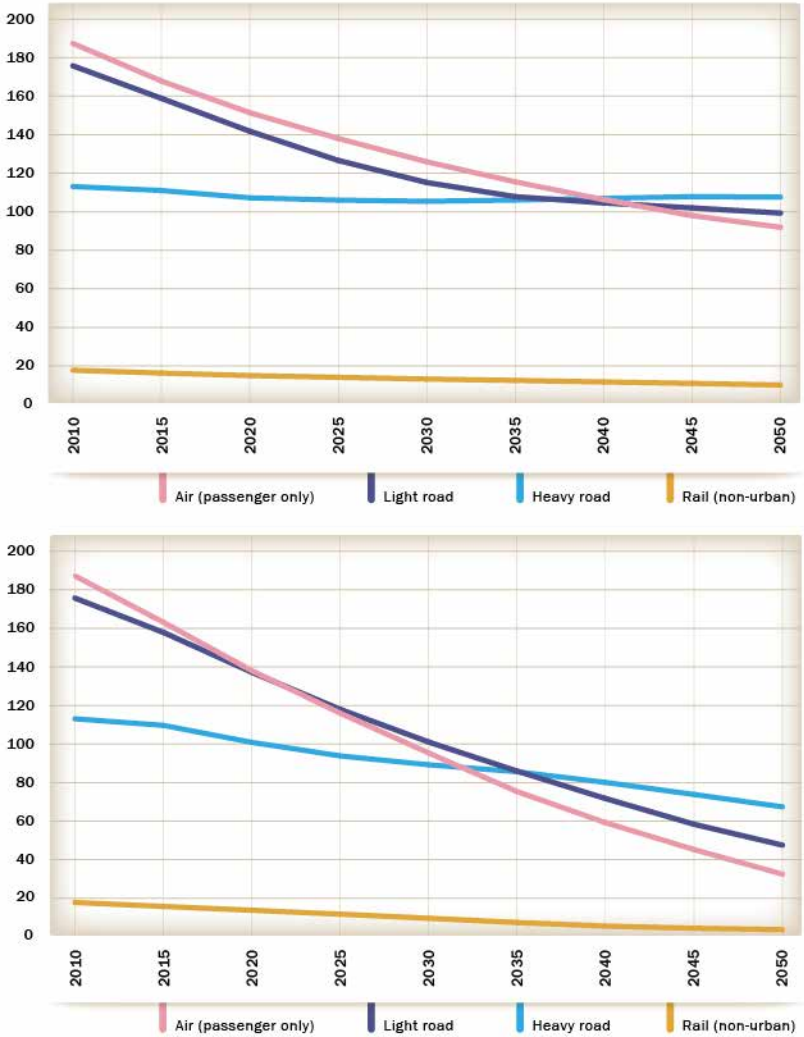
Fig. 101: **Specific energy intensity for different modes of transport according to the 4 Degree (top) and 2 Degree (bottom) scenario, (kJ/TU)**



Source: Elaboration by SUSDEF based on IEA (2016b)

Note: The IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C. The IEA 4 Degree Scenario takes into account recent pledges by countries to limit emissions and improve energy efficiency, which help limit the long-term temperature increase to 4°C.

Fig. 102: **Specific CO_2-eq intensity for different modes of transport according to the 4 Degree (top) and 2 Degree (bottom) scenario, (gCO_2-eq/TU)**



Source: Elaboration by SUSDEF based on IEA (2016a)

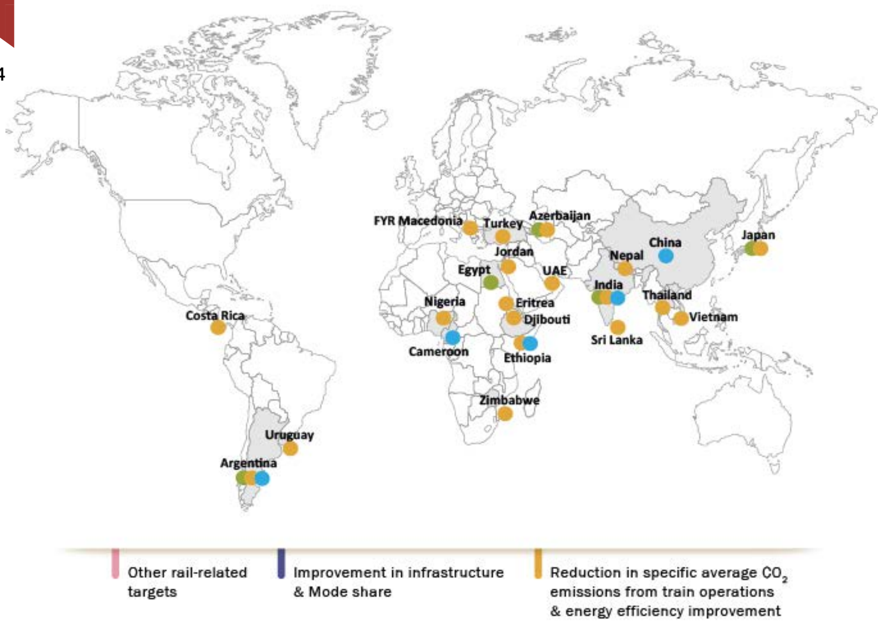
Note: The IEA 2 Degree Scenario, or 2DS, describes an energy system consistent with an emissions trajectory with a 50% chance of limiting average global temperature increase to 2°C. The IEA 4 Degree Scenario takes into account recent pledges by countries to limit emissions and improve energy efficiency, which help limit the long-term temperature increase to 4°C.

Comparison to (I)NDCs targets

Intended Nationally Determined Contributions (INDCs) is a term used under the United Nations Framework Convention on Climate Change (UNFCCC) which refers to the actions that a national government intends to take under the Paris Agreement, which was adopted in December 2015 at the 21st session of the Conference of the Parties (COP21). Since the Nationally Determined Contributions are no longer considered "Intended" at the moment a Party joins the Paris Agreement, it is considered appropriate to use the acronym of (I)NDC, in order to avoid any misunderstanding between intended and approved. These actions together pursue to limit the average global temperature increase to 2°C. A detailed review by the Sustainable Low Carbon Transport Partnership (SLOCAT) of 160 (I)NDCs indicates that about 75% of (I)NDCs have proposed transport sector as a mitigation source and about 67% of (I)NDCs have highlighted specific transport mitigation measure (SLOCAT, 2016). However, only about 19% of (I)NDCs aim for an improvement of the railway sector. About 32 (I) NDCs prioritize improvements regarding the railway sector as a significant emission mitigation measure. These (I)NDCs mostly focus on proposals concerning a shift of transport activity from other transport modes to low carbon rail transport, improving energy efficiency of railway operations, and reducing specific CO_2 emissions from train operations (SLOCAT, 2016).

Figure 103 shows all countries that have included mitigation measures related to the railway sector in their (I)NDCs, with some detailed examples in Table 20.

Fig. 103: **Map of countries that include rail projects in their (I)NDCs and targets related**



Source: Elaboration by SUSDEF based on UNFCC (2015) and SLOCAT (2016)

Table 20: Examples in rail-specific (I)NDC measures in a selection of countries

COUNTRY	Improvement in Infrastructure & Mode share	Reduction in specific average CO_2 emissions from train operations & energy efficiency improvement	Other rail-related targets
ARGENTINA	Revival of passenger and cargo railways, renewal and improvement of rail.	Incorporation of technologies and services that contribute to the modernization and efficiency of the public rail transport system.	Argentina has developed a regulatory framework (Law No. 27,132) that declares railways to be of national public interest and a priority objective for Argentina.
AZERBAIJAN	Development of metro transport and the construction of a number of metro stations.	Electrification of railway lines and the transition to Alternating Current (AC) system in traction.	
CHINA			A target relating to the share of public transport in motorized travel in big-and medium-sized cities, which is aimed at 30% by 2020.
DJIBOUTI	Construction of a 752 km railway line between Djibouti City and Addis Ababa. It is scheduled to be put in service in October 2015.		
INDIA	Increase the share of Railways in total land-based transportation from 36% to 45%. Dedicated Freight Corridors (DFCs) have been introduced across the country. In the first phase, two corridors are being constructed: Mumbai-Delhi (Western Dedicated Freight Corridor) and Ludhiana-Dankuni (Eastern Dedicated Freight Corridor).	With a number of energy efficiency measures undertaken, Indian Railways has achieved 19.7% improvement in Specific Fuel Consumption for Freight Service Locomotives and 21.2% improvement for Coaching Service Locomotives during the last 10 years. Indian Railways is also installing solar power on its land and roof tops of coaches. The DFC is expected to reduce emissions by about 457 million tonnes of CO_2 over a 30 year period.	Railways to be included in a market based energy efficiency trading mechanism.

COUNTRY	Improvement in Infrastructure & Mode share	Reduction in specific average CO_2 emissions from train operations & energy efficiency improvement	Other rail-related targets
JAPAN	Modal shift to railway.	Energy efficiency improvement in railways.	
URUGUAY	Improve the efficiency of cargo transport, through the incorporation of new multimodal systems, and increase the use of railroad and inland waterway transport.		
VIETNAM	Restructure freight towards a reduction in the share of road transport to the benefit of an increase in the share of transportation via rail and inland waterways.		
ZIMBABWE		Refurbishment and electrification of the rail system.	

Source: Elaboration by SUSDEF based on UNFCC (2015) and SLOCAT (2016)

Table 21: (I)NDCs target for total CO_2 emissions

COUNTRY	(I)NDCs TARGET	UNIT OF MEASURE	BASELINE	HORIZON
EU 28	-40%	TOTAL CO_2	1990	2030
USA	-25%	TOTAL CO_2	2005	2025
JAPAN	-26%	TOTAL CO_2	2013	2030
RUSSIA	-75%	TOTAL CO_2	1990	2030
INDIA	-35%	CO_2/GDP	2005	2030
CHINA	-65%	CO_2/GDP	2005	2030

Source: Elaboration by SUSDEF based on UNFCCC (2015)

Actions and technologies supporting future improvements in the railway sector

Energy efficiency improvement is one of the main objectives of railways companies in the context of achieving their environmental and operational objectives.

Improvement efforts in the railway sector can be divided into four primary categories:

Area 1 - Measures related to the design of the infrastructure, installations, and rolling stock

• Efficient infrastructure reducing braking in locomotives, leading to a reduction of energy losses
Example: constructing an upward gradient at the entrance of a station has been proven to result in a savings of 5% in energy consumption from friction and 23% in energy consumption from braking (Shu-Ta Yeh, 2003).

• New train design to reduce drag resistance
Example: a 25% aerodynamic drag reduction leads to a 15% reduction in energy consumption (Turner, 2013).

• Introducing of new materials for light-weight rolling stock
Example: composite materials may reduce energy consumption by 5% (REFRESCO Project, 2016).

• Use of renewable energy sources to supply non-operational energy needs (stations, etc.)

Area 2 - Power traction

• Electrification of railway lines to replace diesel traction
Example: rail electrification could reduce energy consumption by 19-33% (Network Rail, 2009).

• Deployment of new technologies reducing losses in the traction chain
Examples:

- an AC asynchronous traction motor with Insulated Gate Bipolar Transistor (IGBT) inverters may reduce the energy consumption by 15% (UIC, 2003).
- the inclusion of reversible substations in the power supply system, mainly in DC electricity lines, will allow the recovery of the kinetic energy lost in braking, leading to energy savings between 7% and 15% (Zamora D. 2011).

• Acquisition of new rolling stock using alternative fuels (such as liquid gas or hydrogen fuel cells)

Area 3 - Technologies that allow energy savings in ancillary systems

• On-board ancillary systems
Examples: Heating, Ventilating and Air Conditioning (HVAC) technologies or new lighting systems

• Infrastructure's ancillary system
Example: new efficient point heaters with improved insulations and regulation have yielded average energy savings of 30% compared to conventional point heaters (Eltherm GmbH, 2016).

Area 4 - Smart Energy Management

• Improved operational procedures
Example: increasing the load factor can lead to reductions in the specific energy consumption (kWh/pkm). (García Álvarez and Lukaszewicz, 2010) suggest a range of reduction between 15% and 17%.

• Energy efficient driving
Example: eco-driving systems or knowledge and experience sharing between drivers can cut energy consumption to 25% (B-Logistics, 2016).

• Introduction of Energy Storage Systems in the power network
Example: improved energy management may lead to a reduction in energy use between 10% and 30%, with a substantial reduction in power peaks (50%) (Steiner, 2006); smart grid technologies have the capacity to reduce power peaks in specific network locations and demonstrated the ability to reduce energy use by 11% (MERLIN Project, 2015).

Methodology Notes

Railway specific energy consumption (fig. 15, 28, 40, 52, 64, 76) and specific CO_2 emissions (fig. 16, 29, 41, 53, 65, 77) – indicators building

Railway specific energy consumption and specific CO_2 emissions are mainly based on UIC data. The railway companies provide UIC with their tractive stock's total energy consumption split by electric/diesel and passenger/freight activity. These total energy consumptions are combined with pkm and tkm data (allocated to diesel and electricity according to the repartition of passenger and freight train-km), allowing the calculation of energy intensities for passenger and freight activity where company data are available.
When railway companies do not report any energy consumption to UIC, specific energy consumption is estimated using three representative classes of energy intensities: with a low, middle and high energy intensity range approximating the range of values observed for countries where data are reported. One of these three classes is then allocated to countries or regions with insufficient data. The selection of the energy intensity class adopted for specific country level estimates is based on an attempt to minimize inconsistencies with the rail energy consumption reported in the IEA World Energy Balances. This approach can lead to limited inconsistencies with total energy consumption and CO_2 emissions in rail, as the latter use the IEA World Energy Balances as a source.
For a selection of countries/regions – EU, India, Japan, Russia, USA – energy intensities are also calibrated by accounting for additional information (on energy use and related activity) provided by major rail transport operators to UIC on a bilateral basis. Energy intensities are combined with direct CO_2 emissions from fuel combustion (tank-to-wheel CO_2 emissions) and CO_2 emissions resulting from the production and transformation of fuels and electricity (well-to-tank CO_2 emissions) to evaluate CO_2 emission intensities. The emission factors used for this purpose are taken from the IEA Mobility Model.

Railway specific energy consumption and specific CO_2 emissions – consistency improvement

In some cases, figures showing specific energy consumption and specific CO_2 emissions differ from the figures in previous Railway Handbook editions. 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. From the 2015 edition of the Handbook, pkm and tkm data have been systematically derived from train-km and the corresponding load factors, improving the internal consistency of the data. In addition, energy intensity estimates for passenger rail services benefitted from the revision of specific energy consumption per train-km (see methodology note on railway specific energy consumption and specific CO_2 emissions).

Railway energy fuel mix (Fig 13, 25, 38, 50, 62, 74, 86; Table 2, 4, 6, 8, 10, 12, 14)

The railway energy fuel mix has been calculated. The railway energy fuel mix indicates in what proportion different energy sources are being used for rail traction. By applying the electricity mix of the respective country or region to the portion of electric energy used, it is possible to obtain the energy fuel mix shown. In this edition the railway fuel mix is also aggregated by type of source (fossil, renewable, nuclear).

Specific world rail energy consumption (fig. 90) and CO_2 emissions (fig. 91) evolution per traffic unit (TU) between 1990 and 2013 compared to 2030 and 2050 targets

The dataset used for these graphs is a combination of data from the IEA Mobility Model and other sources - mainly UIC Statistics which presents data directly obtained from railway operators (this covered 91% of global energy consumption and 86% of the total world CO_2 emissions by railways in 2013)

Scope of data

The IEA/UIC Railway Handbook intends to provide a global overview of the rail sector, including key world regions. A large amount of effort is dedicated to compile and align different data sources, in order to include the most detailed and accurate indicators possible to the publication. However, the scope and level of detail may vary from one data source to the other. In particular, it should be noted that:

• rail energy use and CO_2 emissions data taken from IEA Statistics (sources referred to as "IEA, 2015a" and "IEA, 2015b") cover all national rail operations, including high-speed, intercity, suburban and urban rail services.

• rail activity, energy use and network extension data are taken from the UIC International Railway statistics publication, the Environmental Performance Database (sources referred to as "UIC, 2015a" and "UIC, 2015b") and bilateral communications between the UIC and rail transport operators. Activity data available in the UIC International Railway Statistics include primarily high-speed and intercity rail services. Suburban or urban rail services are excluded, unless companies also operating long-distance rail services include in their data submission to UIC. In order to align to the UIC International Railway Statistics as closely as possible, suburban and urban rail services are excluded, to the extent possible, from the results reported for the EU, Japan, India, Russia and the USA. That is, those regions where additional data on activity and energy use have been bilaterally collected by UIC (see also the methodology note on "Railway specific energy consumption and specific CO_2 emissions - indicators building"). In future editions, the IEA and the UIC are going to continue to work closely to keep improving the scoping and quality of the data presented in the Railway Handbook.

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.

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

Tractive Stock
Includes locomotives and self-propelled carriages using electricity or diesel (EMU-Electric Multiple Units and DMU-Diesel Multiple Units).

Train-kilometre
Unit of measurement representing the movement of a train over one kilometre.

Traffic Unit (TU)
The sum of passenger kilometre and tonne kilometre.

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

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

CER

Community of European Railway and Infrastructure Companies (CER) is the association representing the interests of European Railways Operators and Railways Infrastructure Companies in Brussels. CER Members covers 73% of the European rail network length, 80% of the European rail freight business and 96% of rail passenger operations in Europe.

EU Climate Package and EU Climate Strategy

The 2020 package is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets: 20% cut in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables, 20% improvement in energy efficiency. The targets were set by EU leaders in 2007 and enacted in legislation in 2009. The 2030 climate and energy framework sets three key targets for the year 2030: At least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 27% share for renewable energy, at least 27% improvement in energy efficiency. The framework was adopted by EU leaders in October 2014. It builds on the 2020 climate and energy package.

ICAO

The International Civil Aviation Organization (ICAO) is a UN specialized agency, established by States in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). ICAO works with the Convention's 191 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector.

IEA Mobility Model (MoMo)

The IEA mobility model (MoMo) is a technical-economic database spreadsheet and simulation model that enables detailed global and regional projections of transport activity, vehicle activity, energy demand, and well-to-wheel GHG and pollutant emissions according to user-defined policy scenarios to 2050. It represents all major motorised transport modes (road, rail, shipping and air) providing passenger and freight services.

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 of America.

OECD North America: Canada, Mexico and United States of America.
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.
Other OECD: Australia, Chile, Israel, Japan, Korea and New Zealand.

SUSDEF

Sustainable Development Foundation founded in 2008 by companies, business associations and sustainability experts, it is a not for profit think-tank based in Rome aimed at encouraging the transition towards a green economy. The Foundation relies on a network of 100 associated green companies and more than 50 top level senior experts and young talents in the sustainable development field.

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