

Environmental impact assessment of rail freight intermodality in Belgium using a LCA approach

Public thesis defense

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I. Introduction

1. Inland freight transport

2. The LCA methodology



II. LCA of inland freight transport in Belgium

3. LCA of rail freight transport

4. LCA of IWW transport

5. LCA of road freight transport

6. Comparison of the environmental impacts of the transport modes



III. Environmental impact assessment of freight transport

7. Study of intermodal freight transport routes



8. Study of the modal split of inland freight transport in Belgium



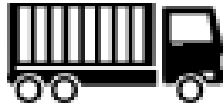
IV. Conclusions and perspectives

9. Conclusions and perspectives



	Transport and Regional Economic	Macro-economic impact and effective market regulation
	Political Science	Effective governance and organization
	QuantOM	Optimal corridor and hub development
	Chemical Engineering	Environmental impact of intermodality

Inland freight transport in Belgium



Road freight transport

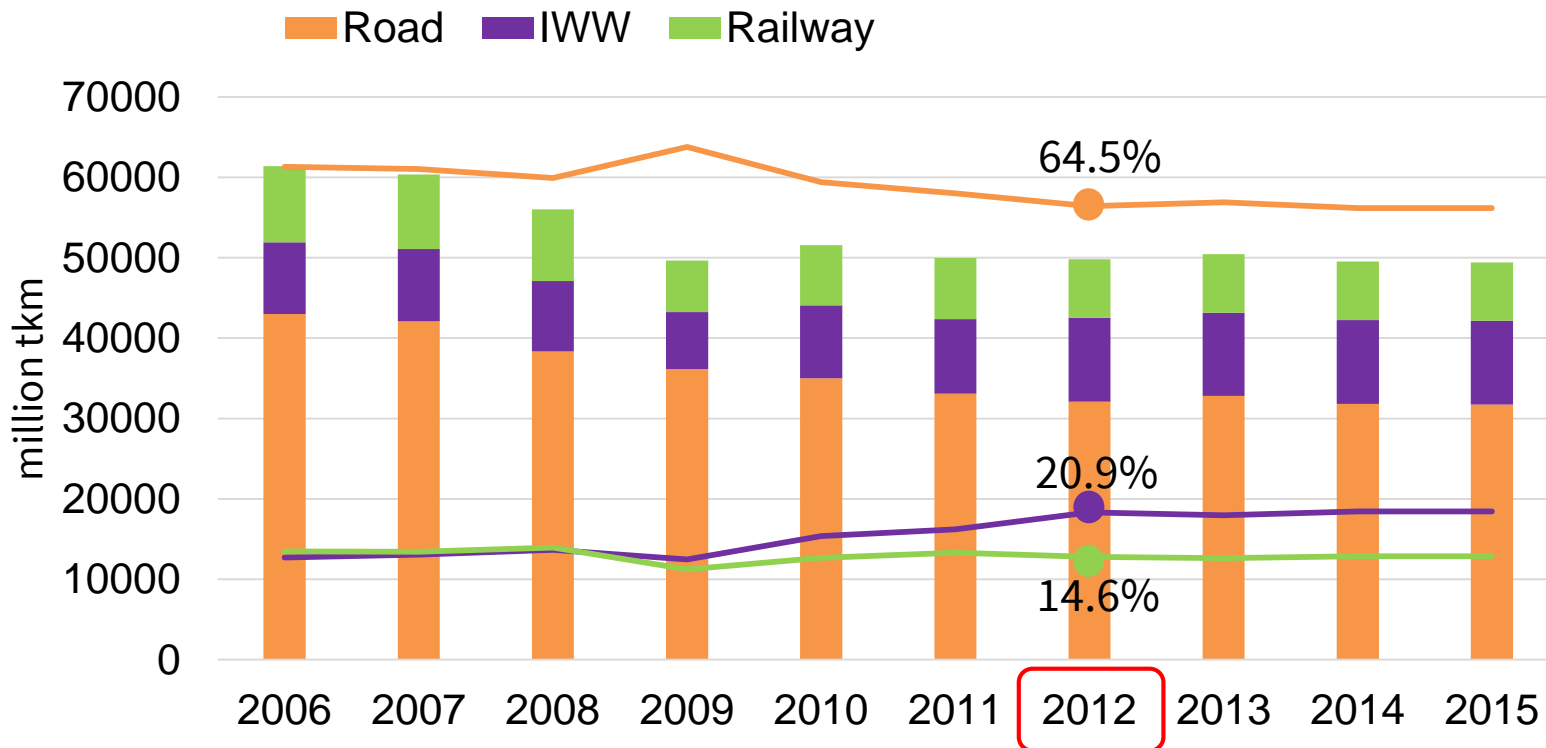


Inland waterways transport (IWW)

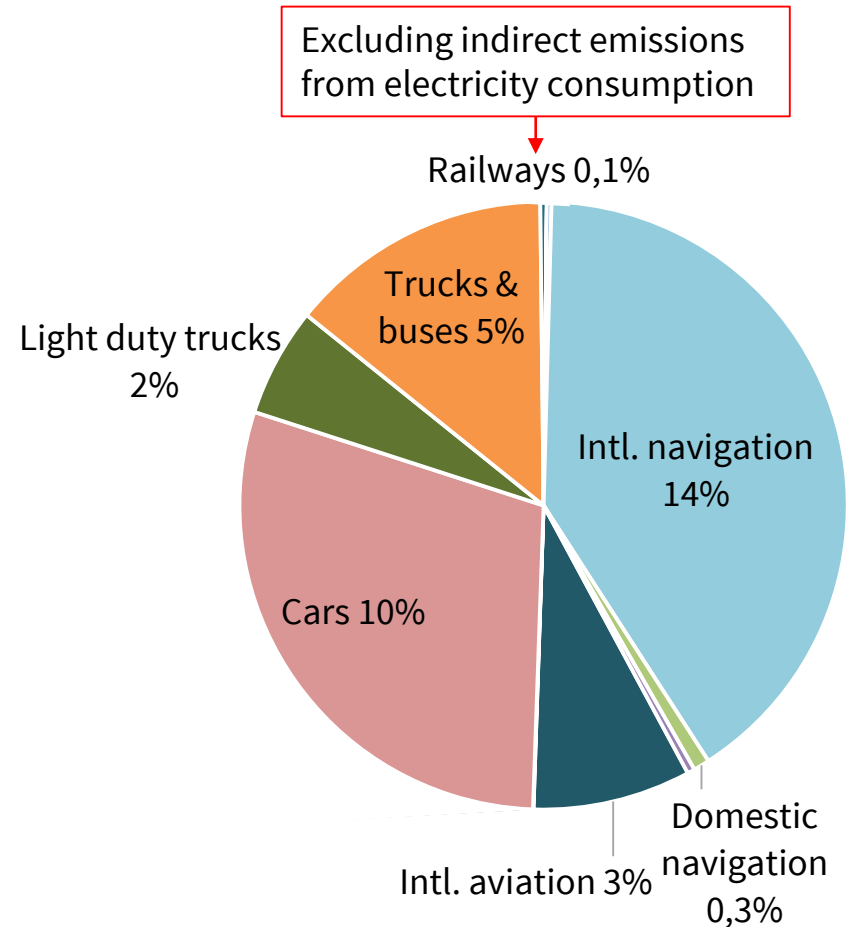
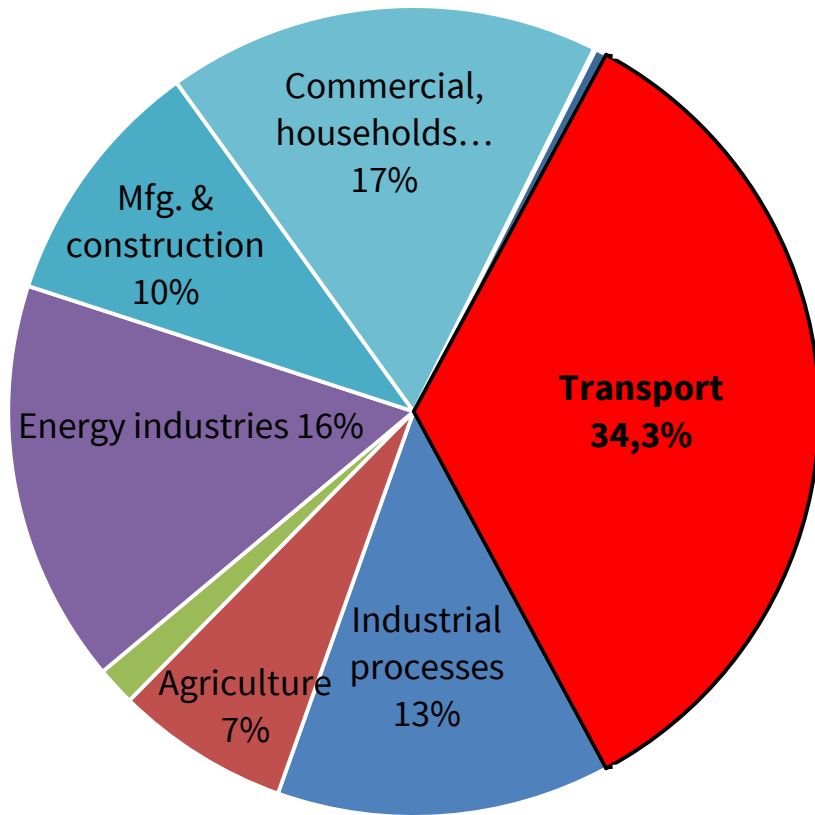


Rail freight transport

Inland freight transport (million tkm) and modal split (%) in Belgium

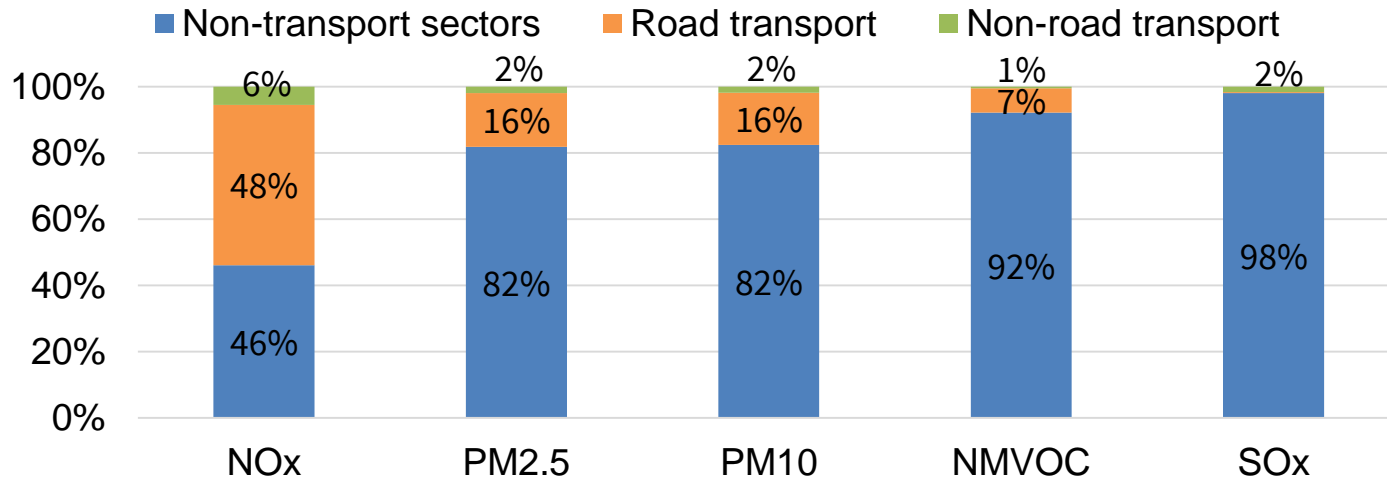


GHG emissions in Belgium in 2012

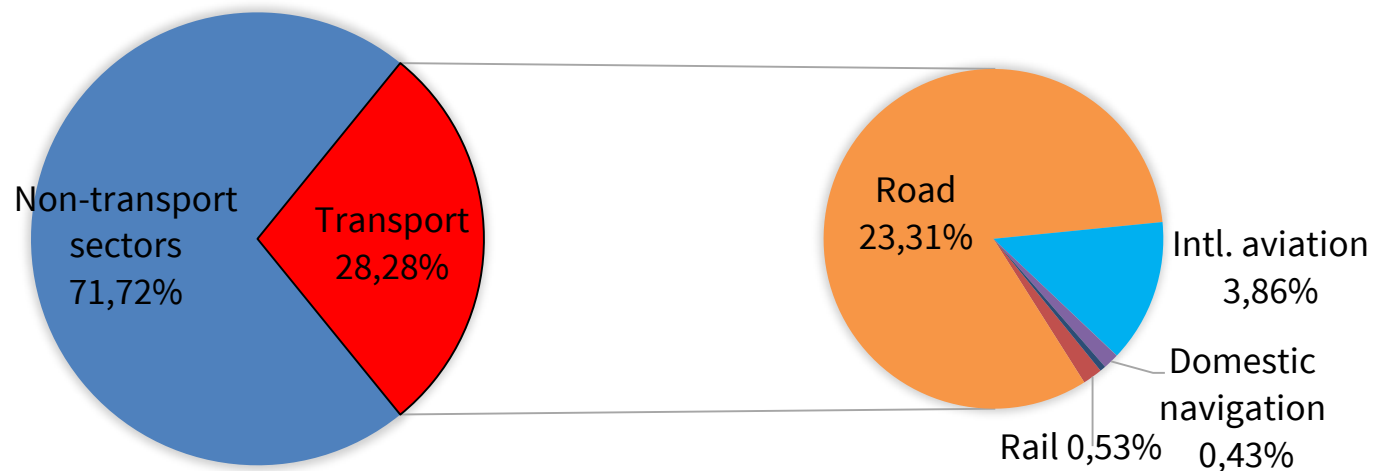


Source: Eurostat statistics, 2017

Air pollution in Belgium in 2012

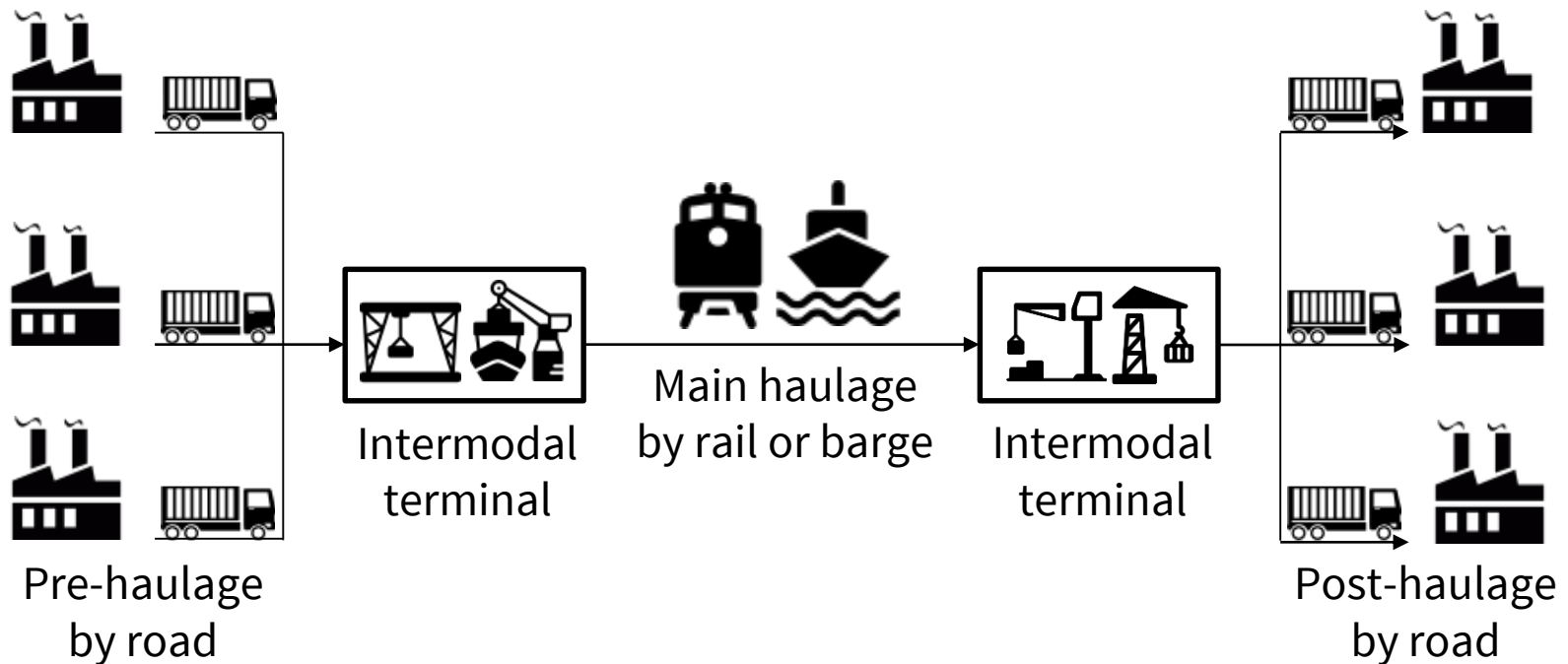


Final energy consumption in Belgium in 2012



Intermodal freight transport

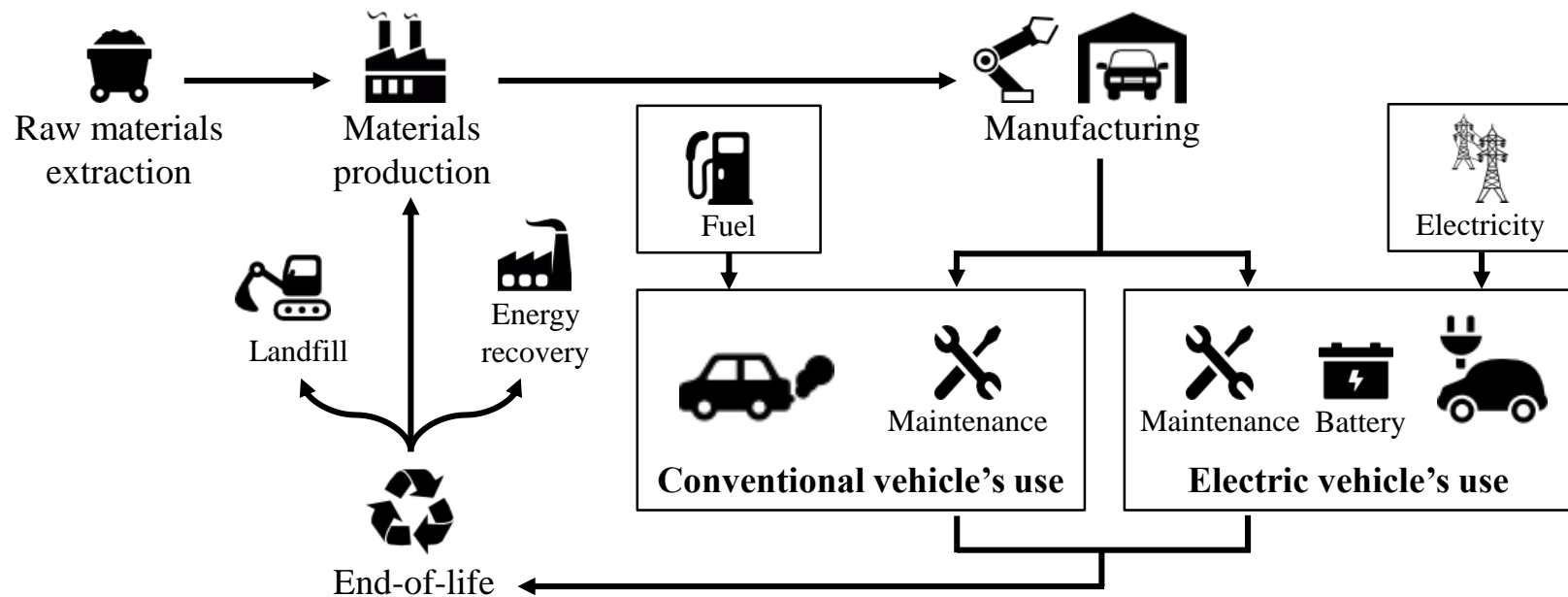
- ▶ Shifting of road transport in long distances to rail or IWW transport
- ▶ Advantages:
 - ▶ Environnemental performance
 - ▶ IWW transport → Highest energy-efficiency
 - ▶ High payload capacity of trains
 - ▶ Reduced externalities: energy consumption, noise, congestion, traffic accidents



- ▶ Weakness of rail freight transport:
 - ▶ Higher investments in infrastructure for passengers
 - ▶ Freight < Passenger (86.5% rail traffic in Belgium in 2009)
 - ▶ Priority of passenger transport over freight transport
- ▶ High operating costs and investments needed for rail freight transport
 - ▶ Belgium: 12 rail freight operators
 - LINEAS 86.62% of tkm in 2012
- ▶ Smaller railway network (3,582 km) compared to road (153,447 km)
 - ▶ Weak access → Lack of direct rail links
 - ▶ Mass use of the rail infrastructure → Poor flexibility

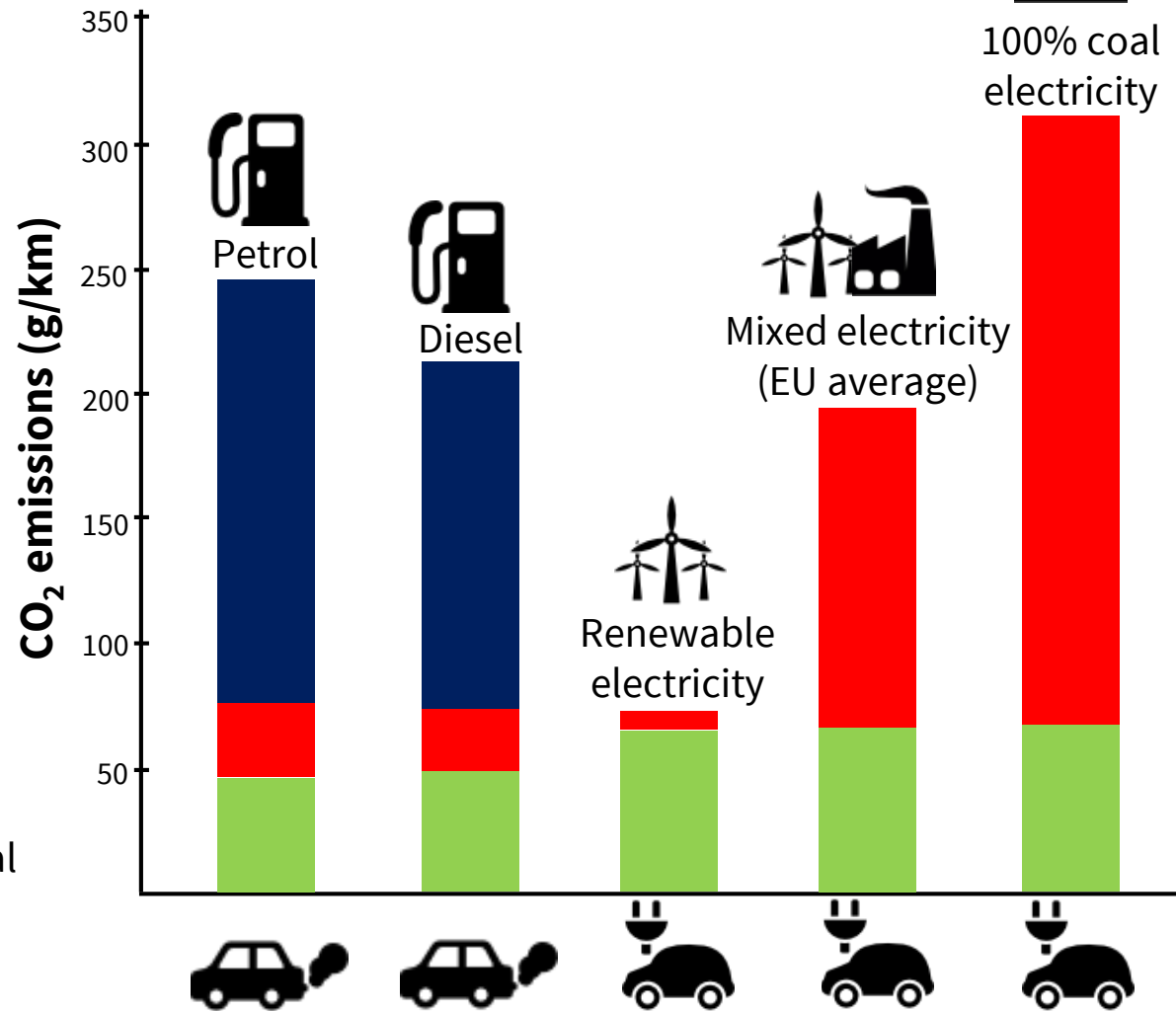
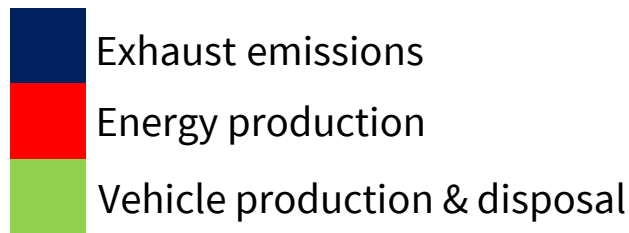


- ▶ Environmental impacts of a product from raw material extraction, through materials use, and finally to disposal

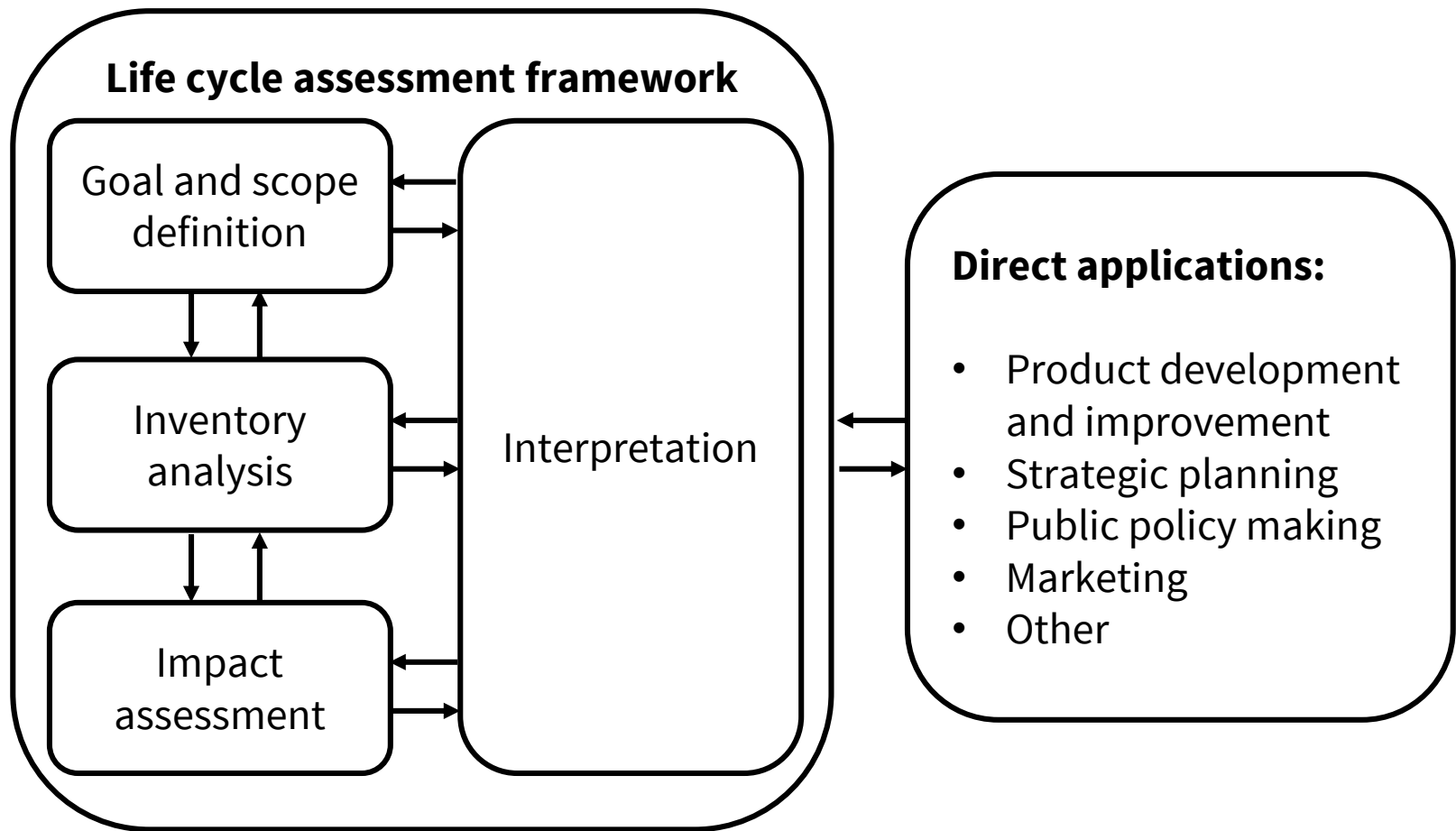


LCA – Cradle-to-grave approach

- Pollution transfer between life cycle stages



- ▶ LCA methodology is a structured, comprehensive and internationally standardized method by ISO 14040 and 14044

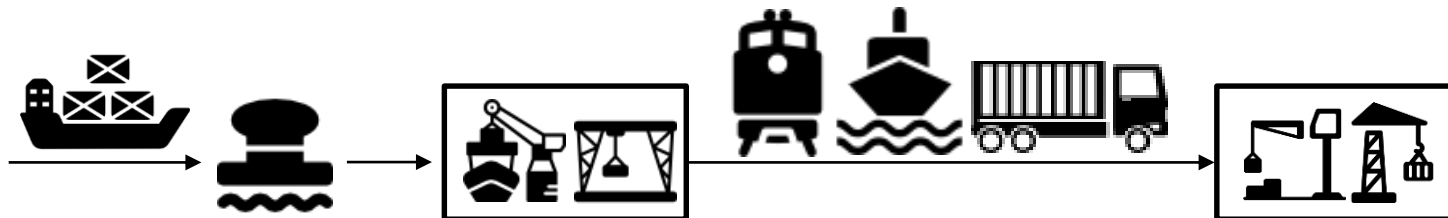


LCA – Goal and scope definition

- ▶ To analyse and compare the environmental impacts of the different inland freight transport modes in Belgium

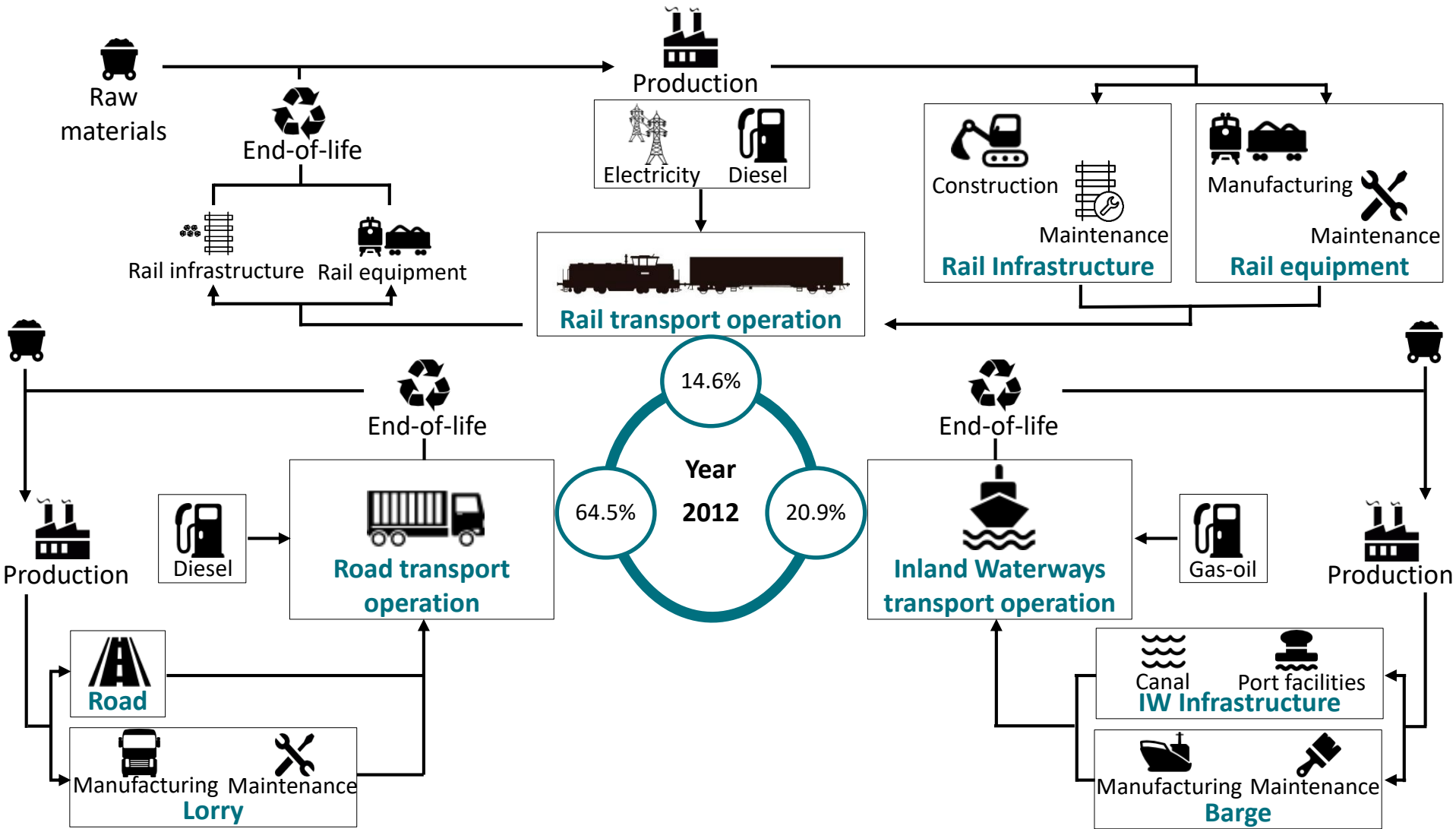


- ▶ Intermodal transport routes

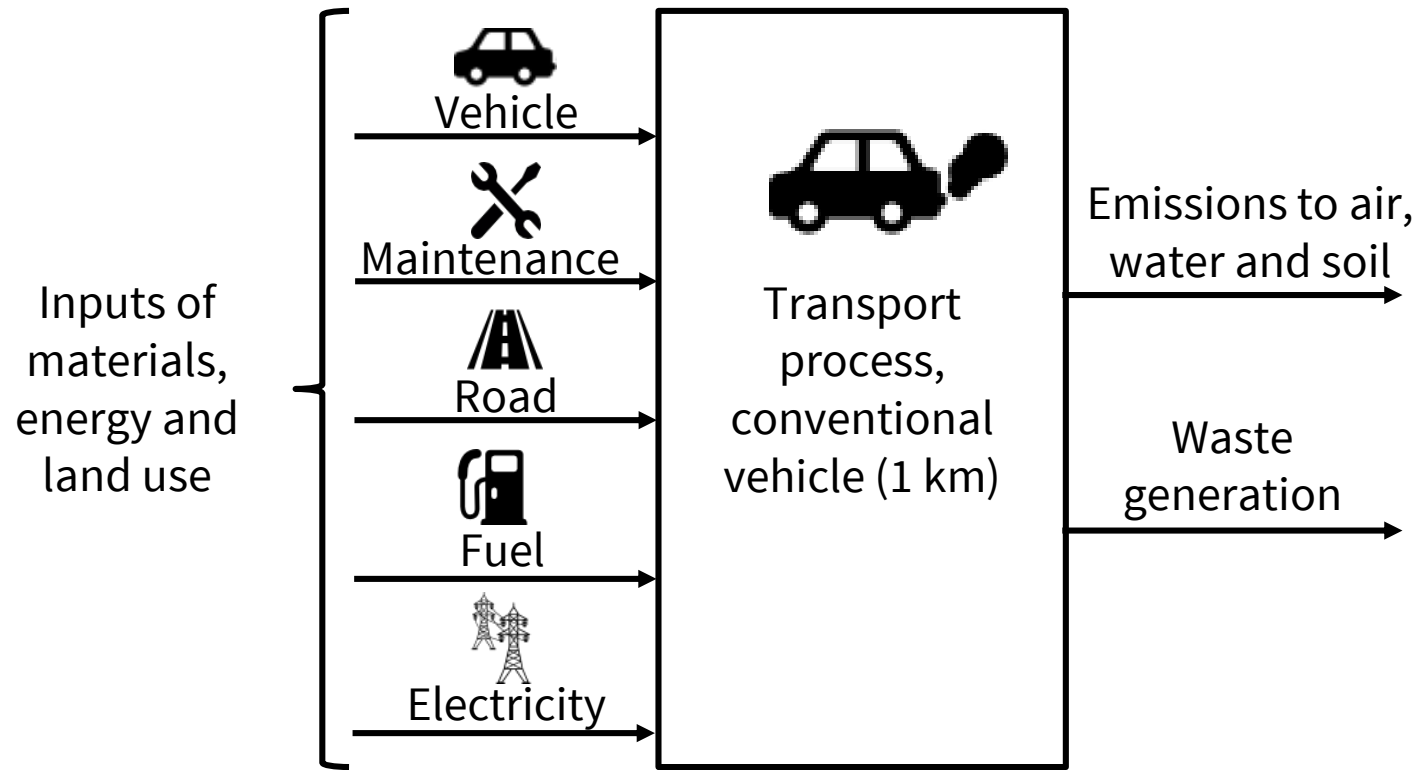


- ▶ Modal splits of inland freight transport in Belgium
- ▶ Functional unit: “1 tkm (tonne-kilometre) of freight transported”

LCA – Goal and scope definition



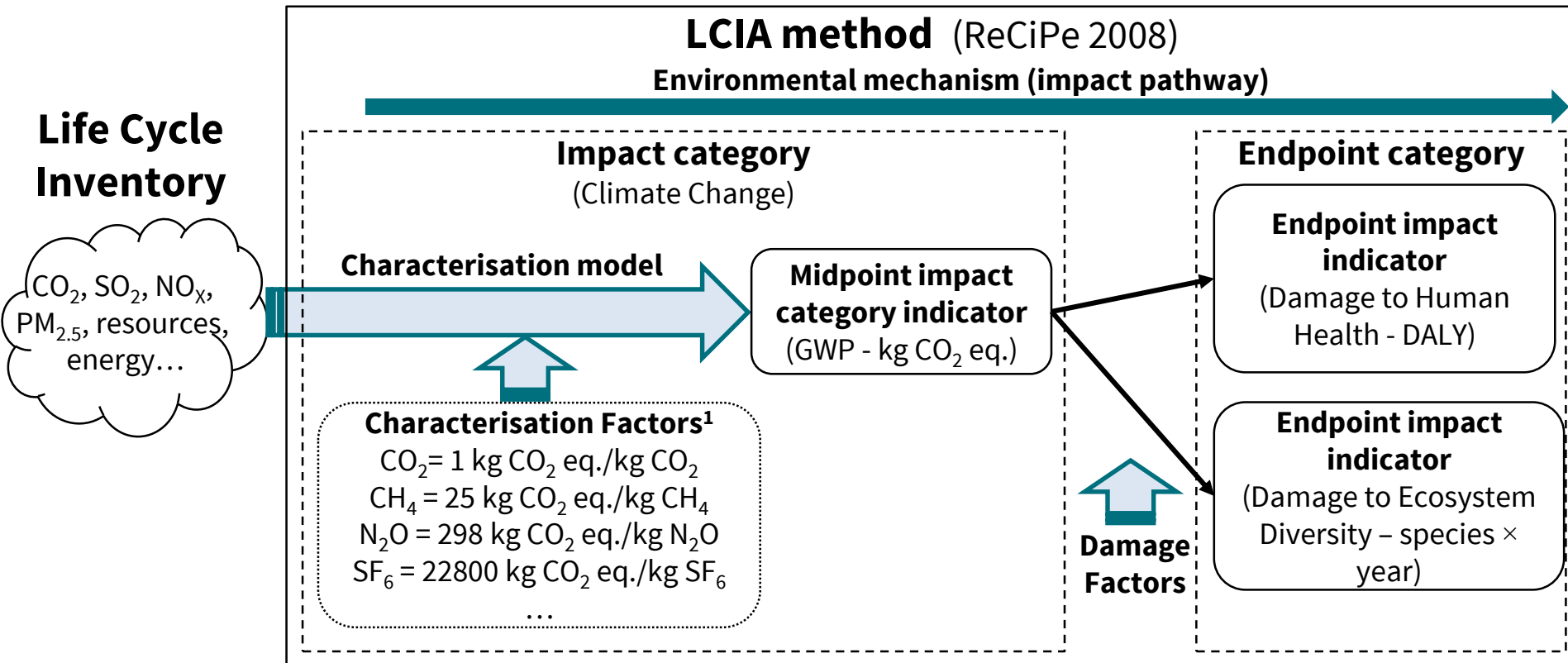
LCA – Life Cycle Inventory (LCI)



- ▶ Commercial databases
- ▶ Stakeholders
- ▶ Software



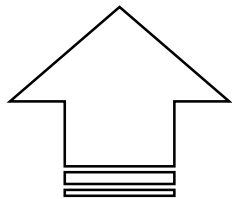
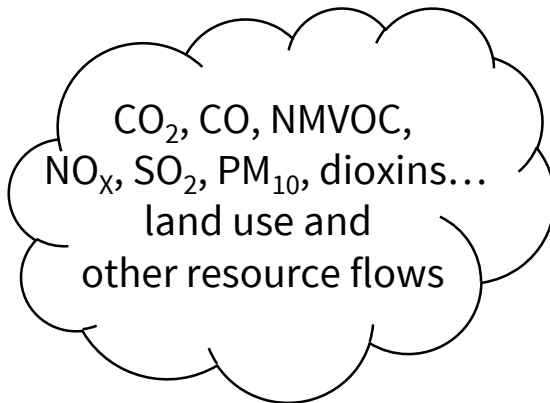
- ▶ The information collected in the LCI is translated into environmental impacts



¹Source: IPCC, 2007

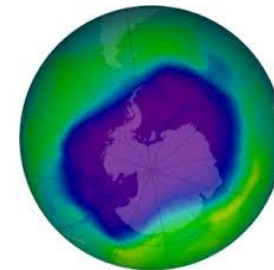
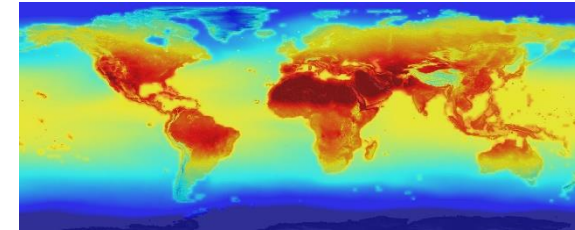
LCIA method – ILCD 2011 Midpoint+

Life Cycle Inventory



Midpoints categories

- Climate change
- Ozone depletion
- Human toxicity, non-cancer effects
- Human toxicity, cancer effects
- Particulate matter
- Ionizing radiation Human Health
- Ionizing radiation Ecosystems
- Photochemical ozone formation
- Acidification
- Terrestrial eutrophication
- Freshwater eutrophication
- Marine eutrophication
- Freshwater ecotoxicity
- Land use
- Water resource depletion
- Resource depletion

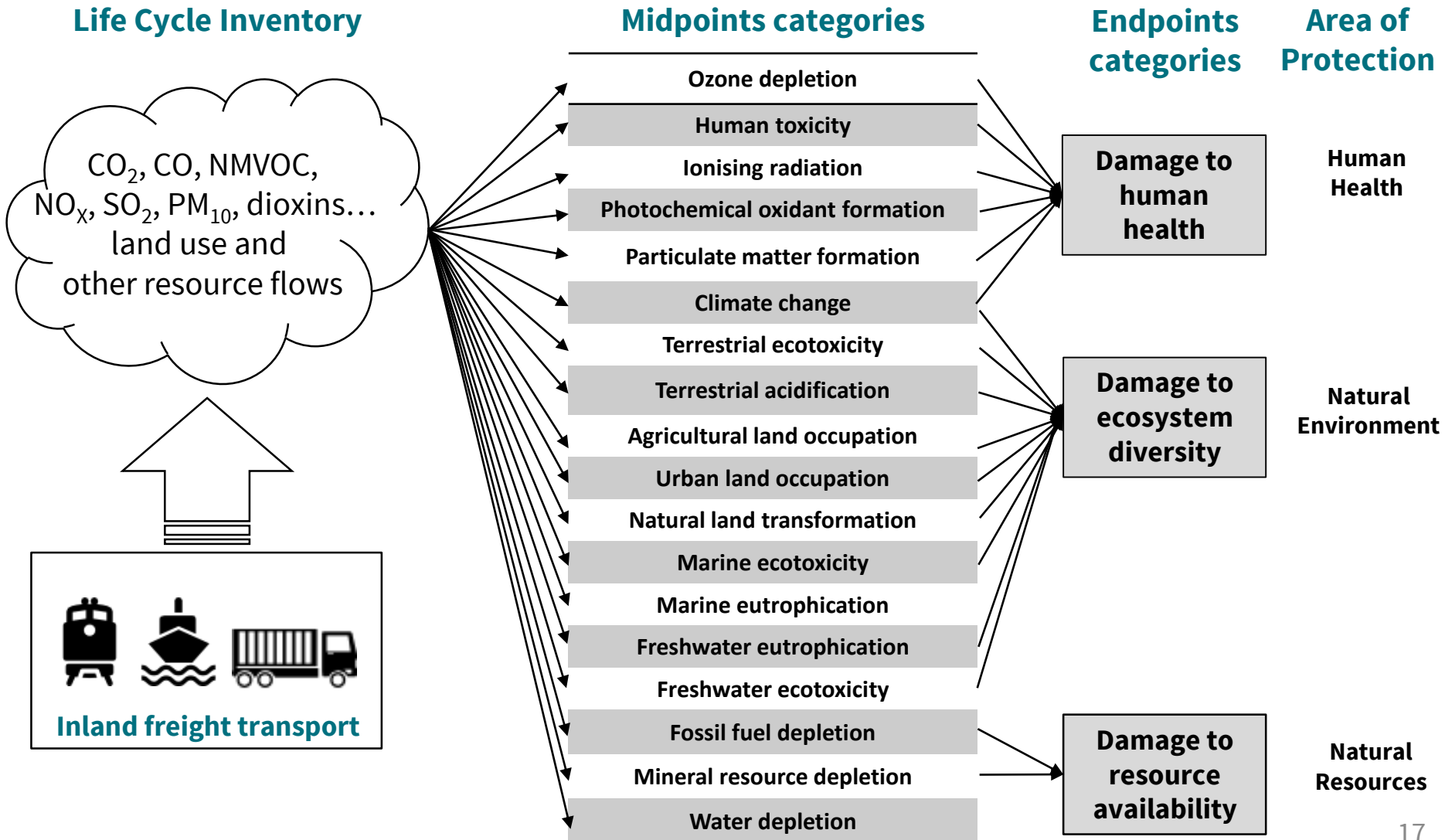


Particulate matter



LCIA method – ReCiPe 2008

Environmental mechanism (impact pathway)



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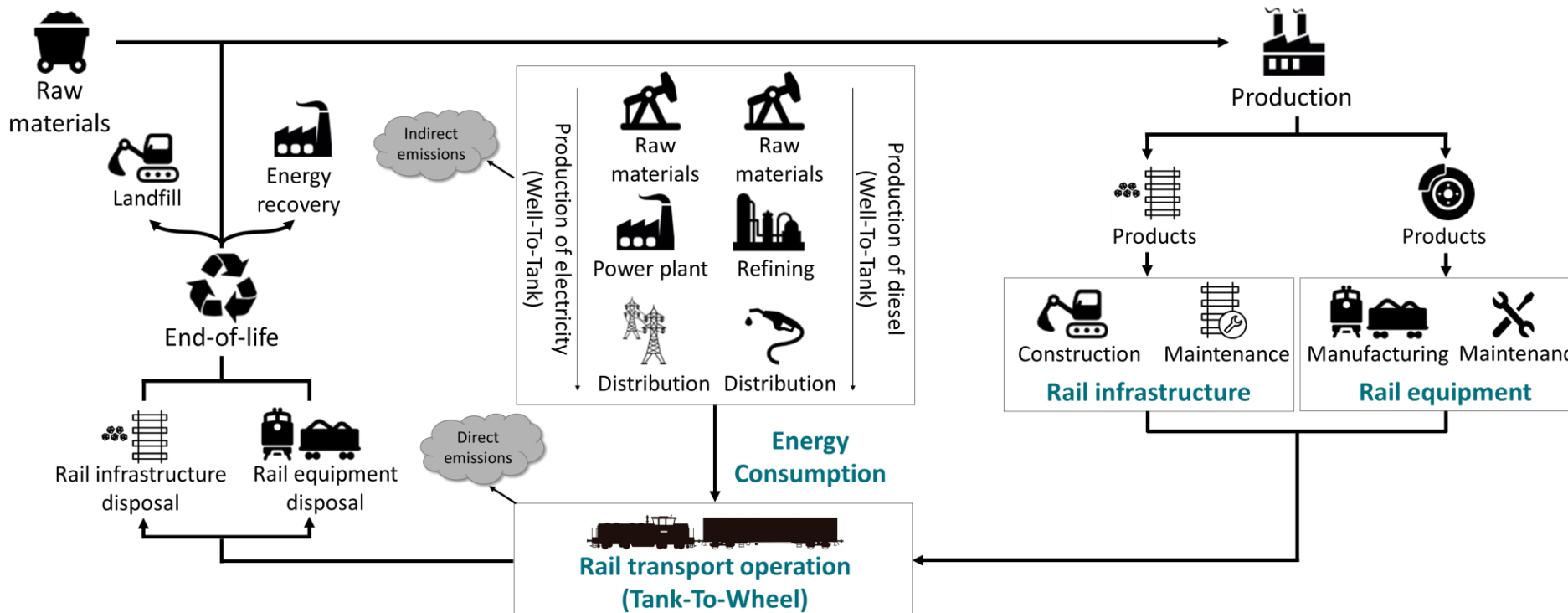
8. Study of the modal split of inland freight transport in Belgium



IV. Conclusions and perspectives

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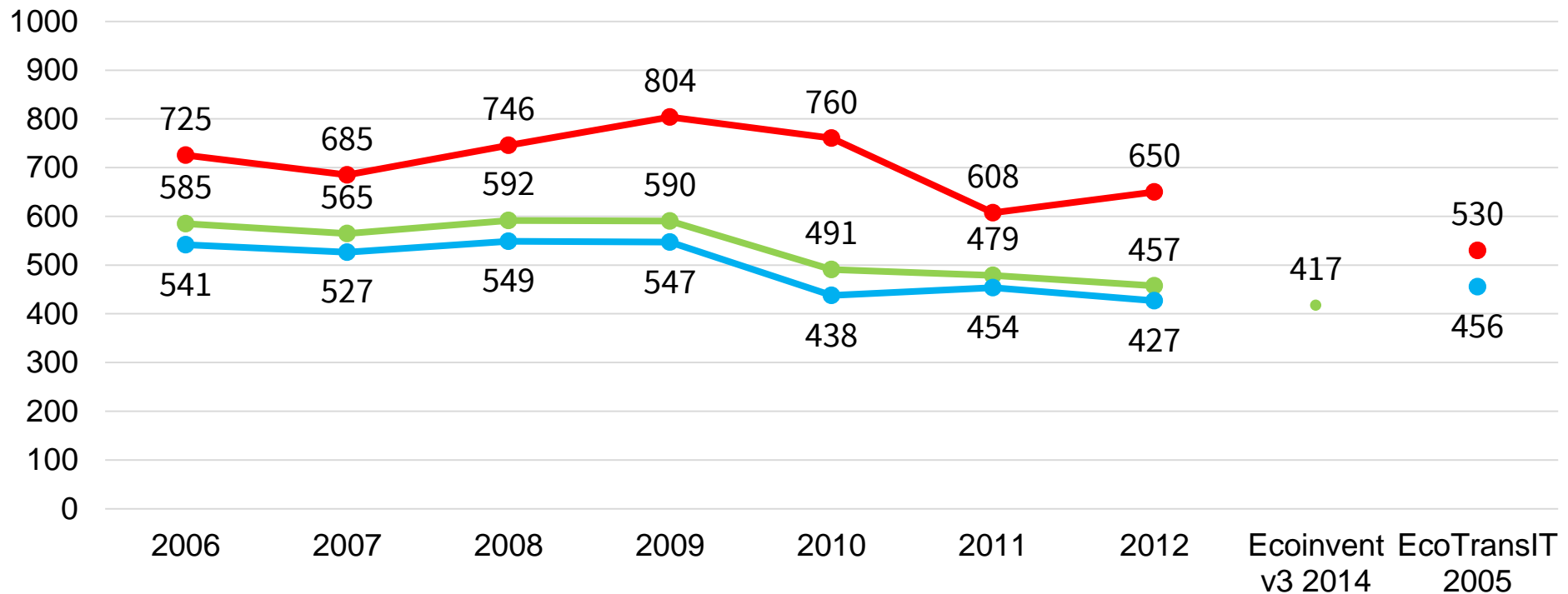
LCA of rail freight transport



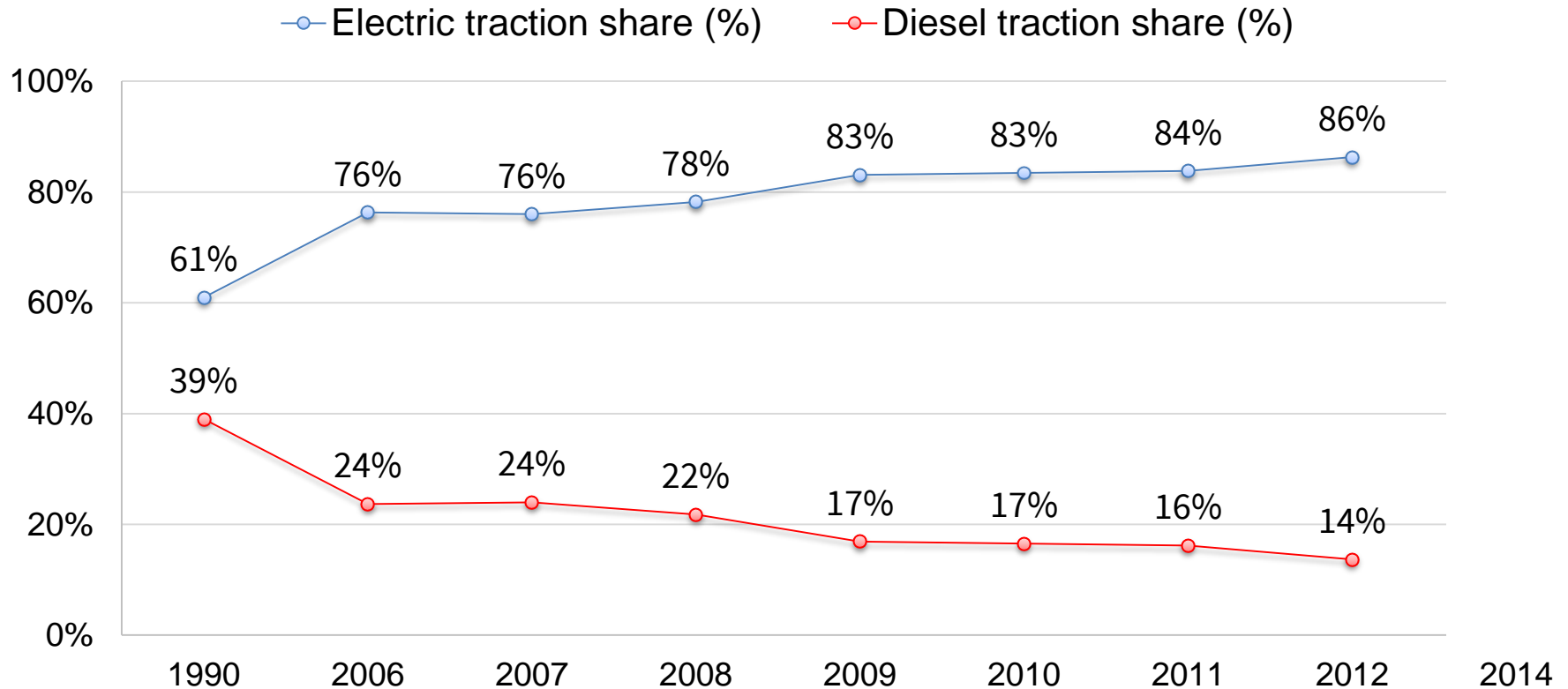
Rail operation: Energy consumption

Energy consumption (kJ/tkm) of rail freight transport

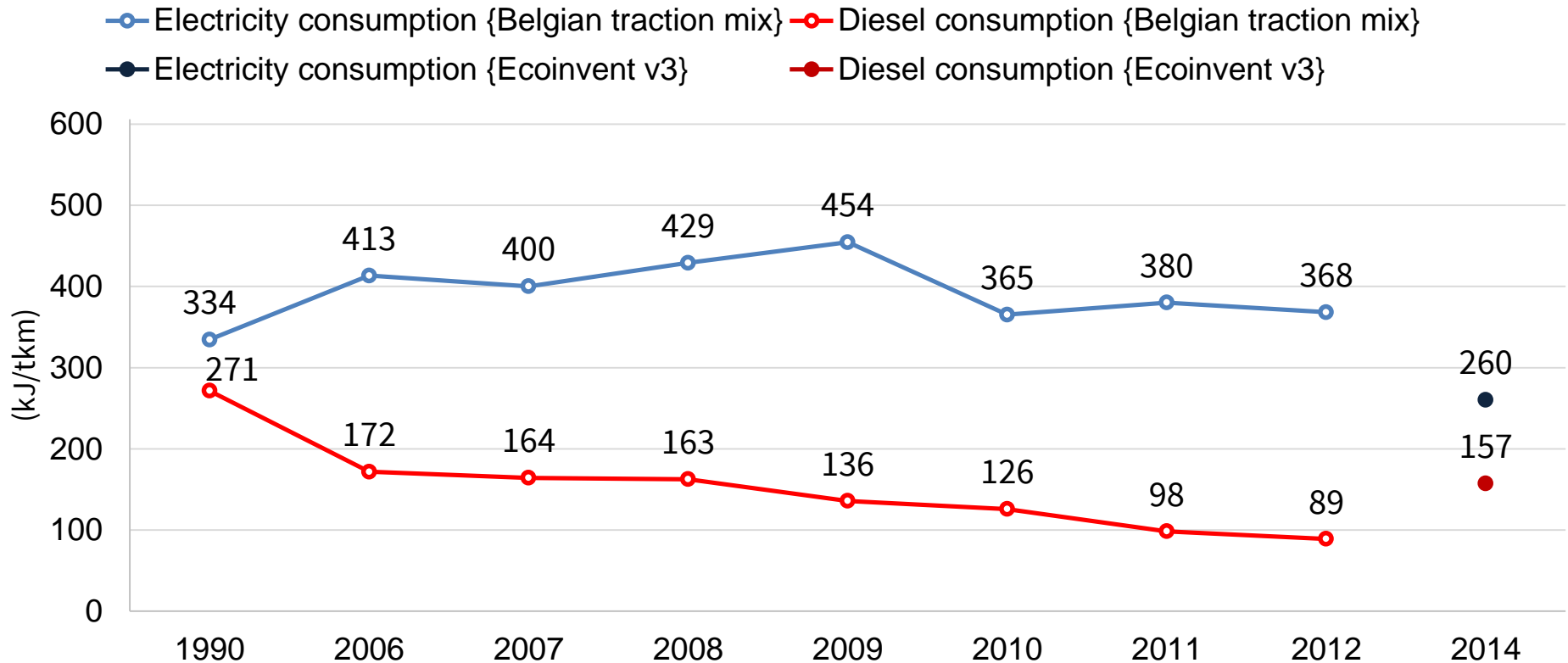
—●— Rail transport (Belgian traction mix) —●— Electric trains —●— Diesel trains



Belgian traction mix



Energy consumption (kJ/tkm) of the Belgian traction mix



- ▶ Exhaust emissions from diesel locomotives

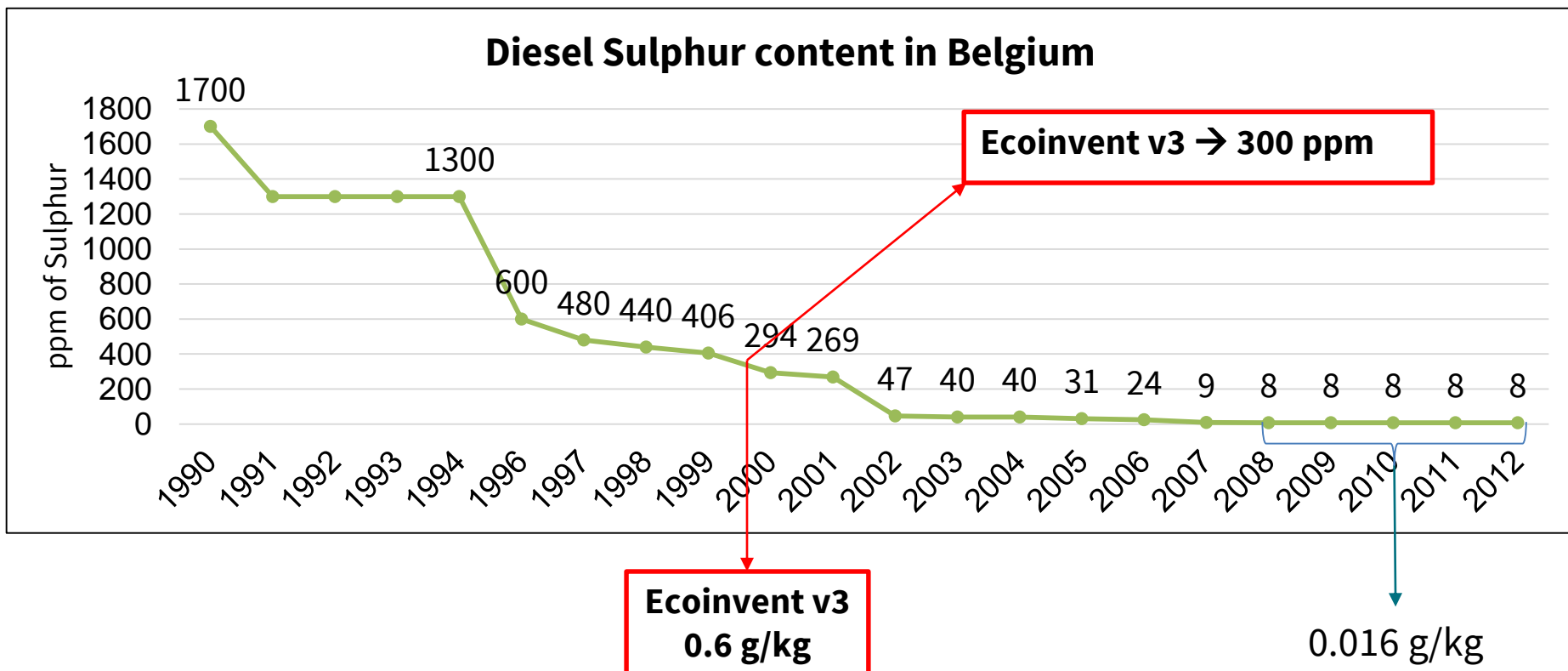
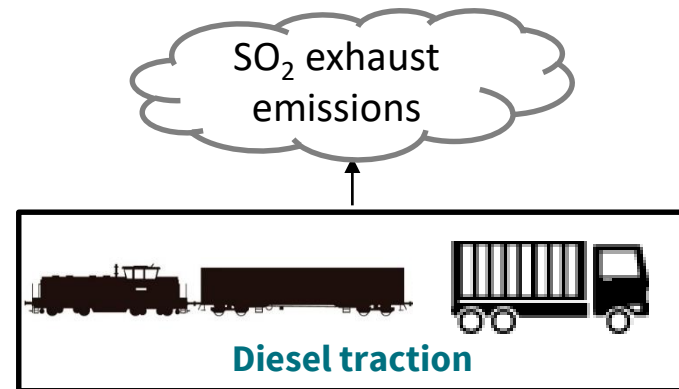
Exhaust emissions to air			
CO ₂	NMVOC	PM	Methane
CO	NH ₃	PM _{2.5}	Toluene
NO _x	N ₂ O	PM ₁₀	Benzene
Heavy metals (Cd, Cu, Cr, Ni, Se, Zn, Pb, Hg)			Xylene

- ▶ Emission to air of SF₆ (electricity consumption)
- ▶ Emission to soil of Fe (wheels, brakes and rails)



Rail operation: Direct emissions

- ▶ Emission to air of SO₂ are dependent on the Sulphur content in the diesel

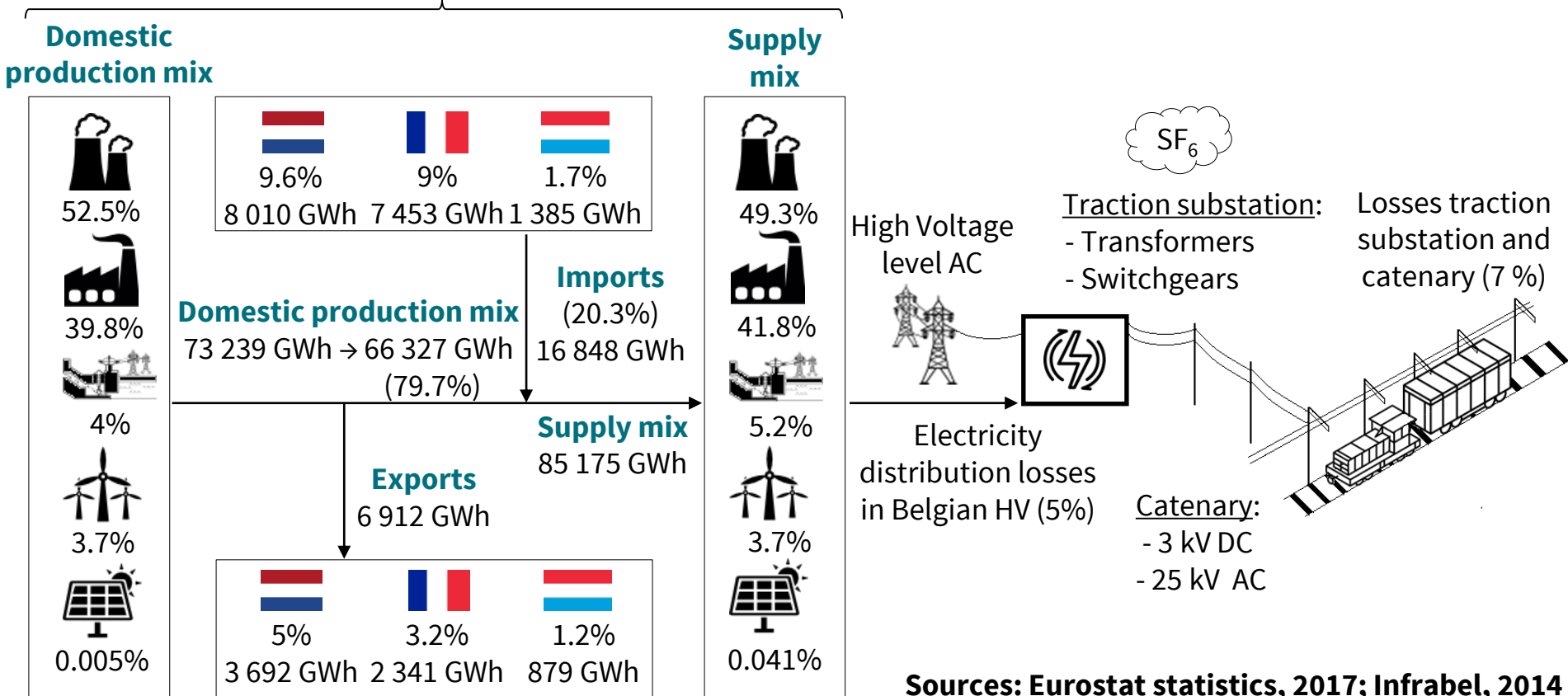


Rail operation: Electricity supply mix

- ▶ Emission factors varies widely as result of a variation in the energy split of the country
- ▶ Domestic production mix \neq Supply mix



Conversion emissions



▶ Locomotives



Diesel
locomotives



Electric
locomotives



▶ Goods wagon

▶ Railway infrastructure

- ▶ Allocation of construction and disposal
- ▶ Allocation of operation and maintenance

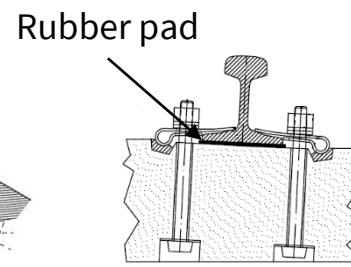
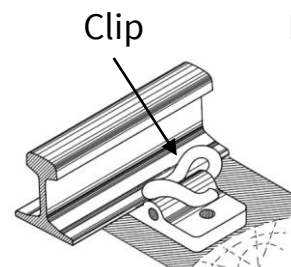
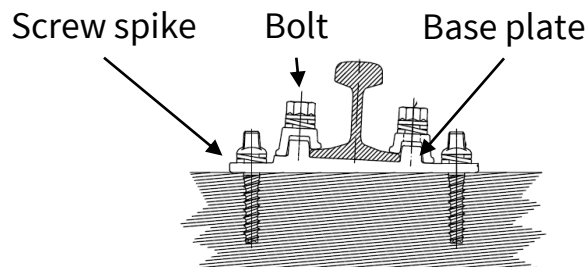
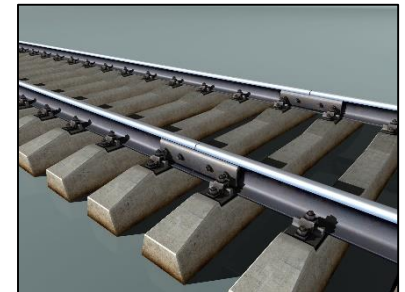
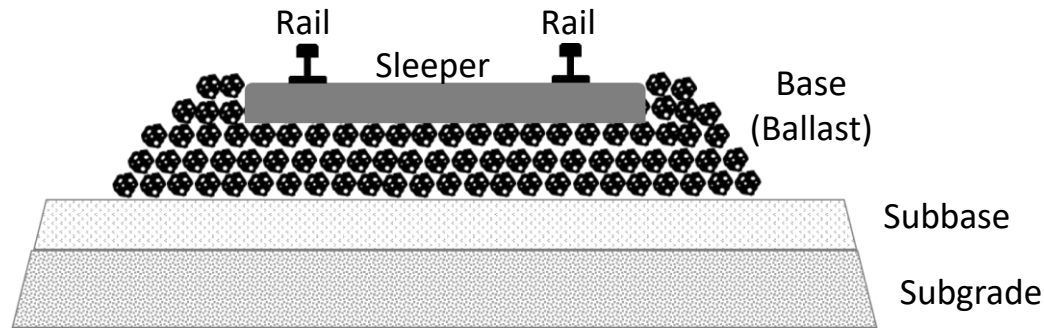


Railway infrastructure

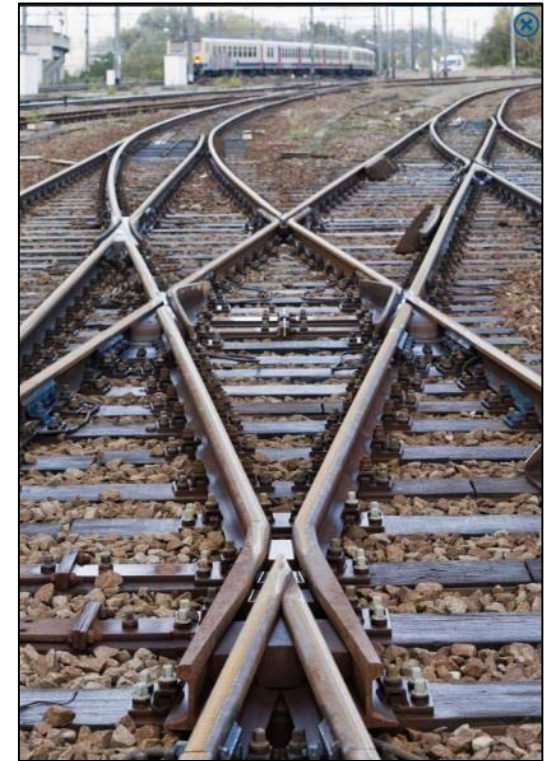
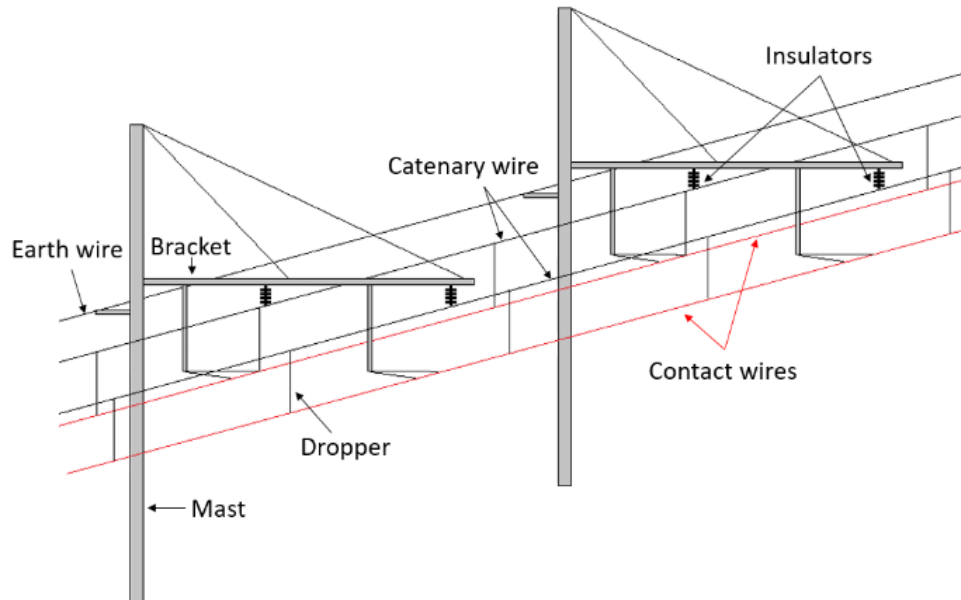
- ▶ The LCI of the Belgian railway infrastructure includes:
 - ▶ Tunnels and bridges



- ▶ Track bedding, rails, sleepers, fastening system



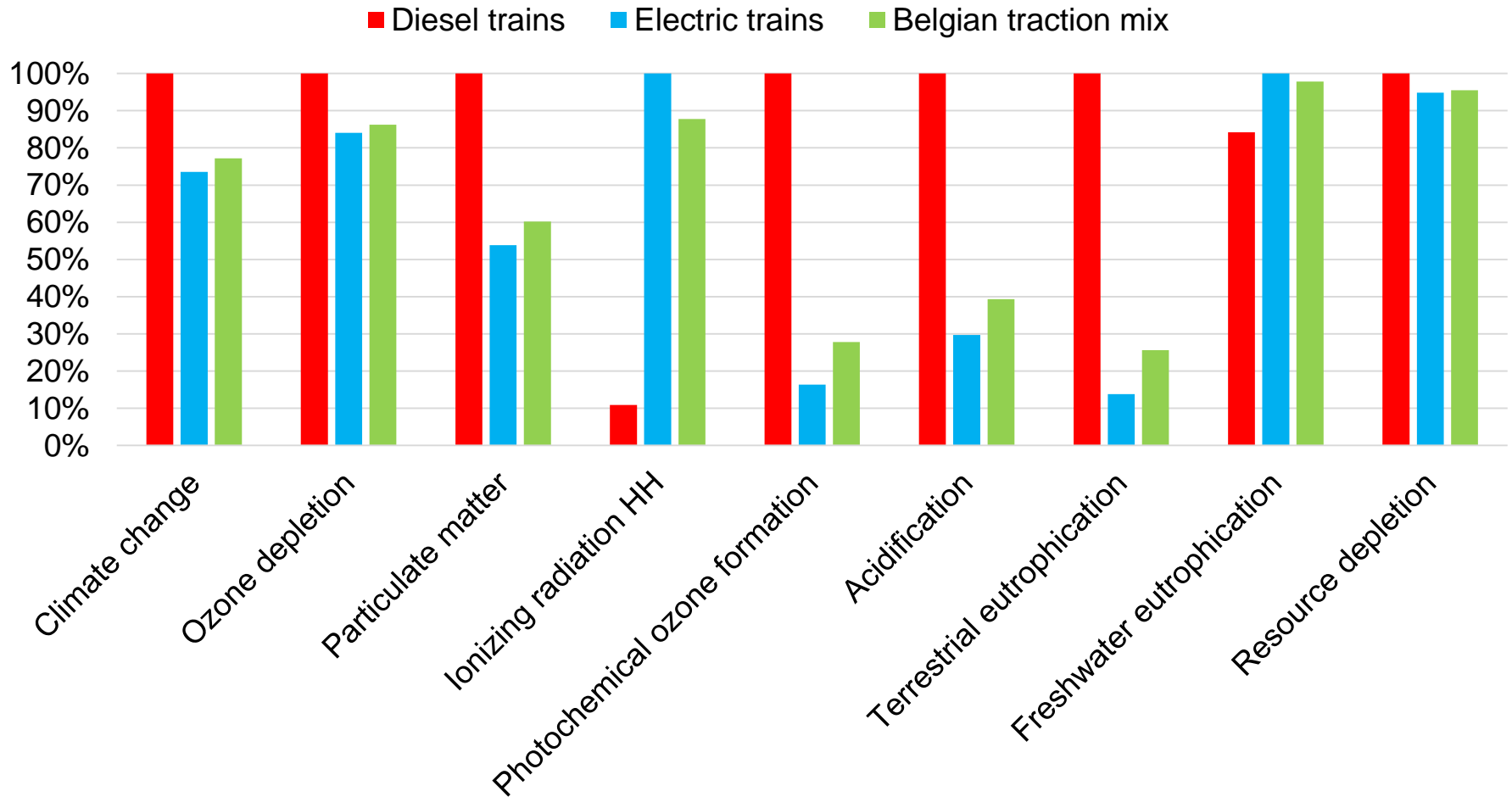
- ▶ Switches and crossings
- ▶ Overhead contact system



- ▶ Maintenance
 - Fuel consumption and exhaust emissions from the machinery
 - New materials in the track renewal
 - Weed control



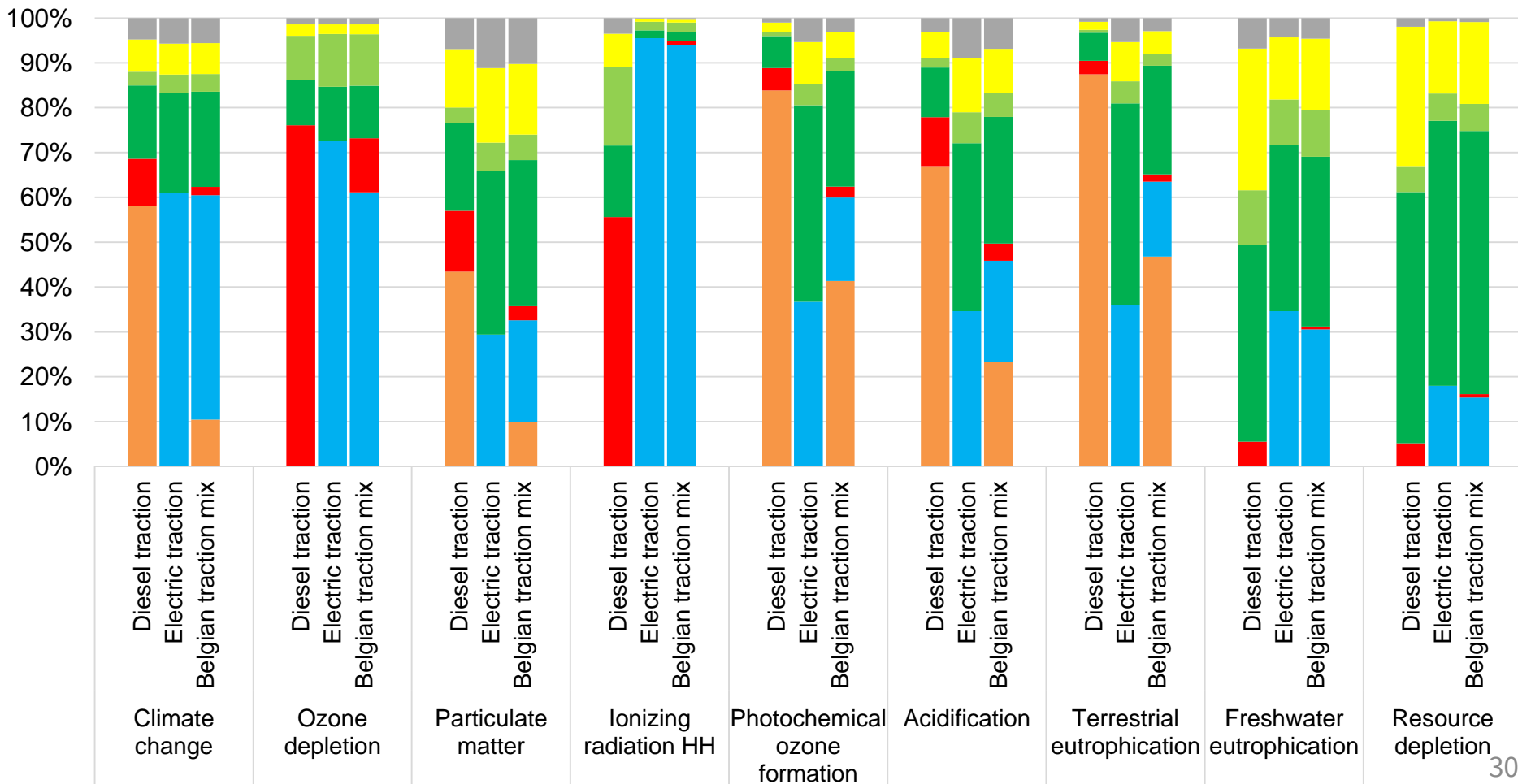
LCIA of 1 tkm of rail freight transport in Belgium in 2012



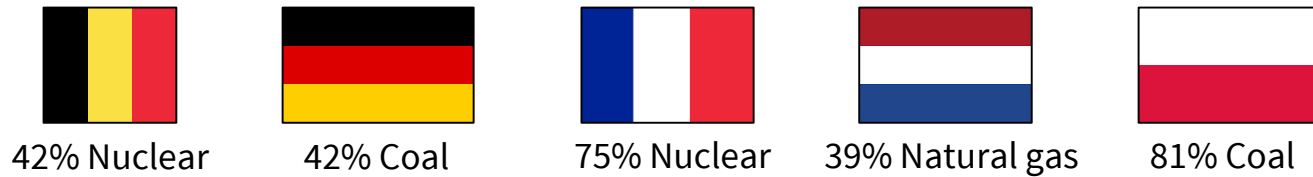
LCIA of rail freight transport

LCIA of 1 tkm of rail freight transport in Belgium in 2012

- Transport operation
- Electricity supply mix
- Diesel
- Railway track construction
- Railway track maintenance
- Rail equipment
- Rail equipment maintenance

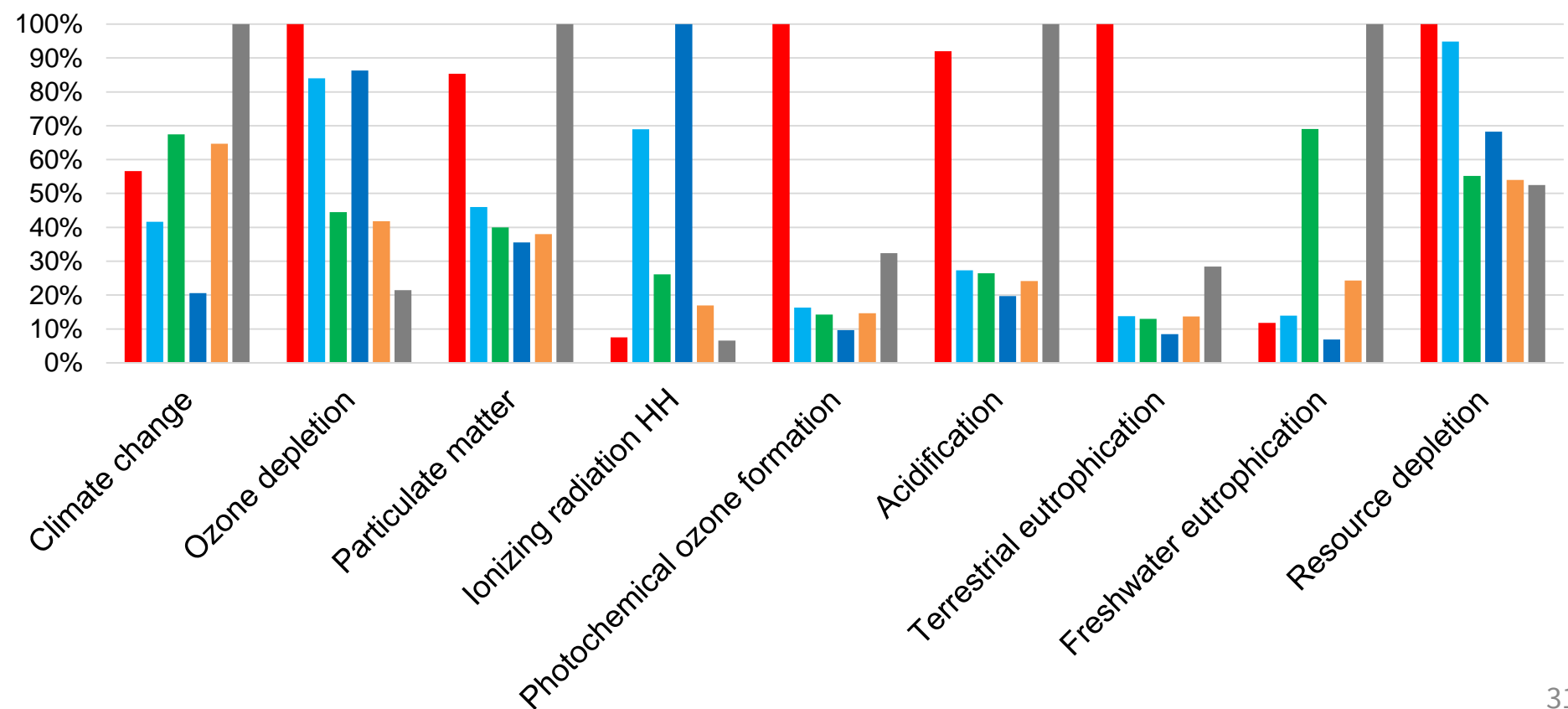


LCIA of electric trains in different countries 2012

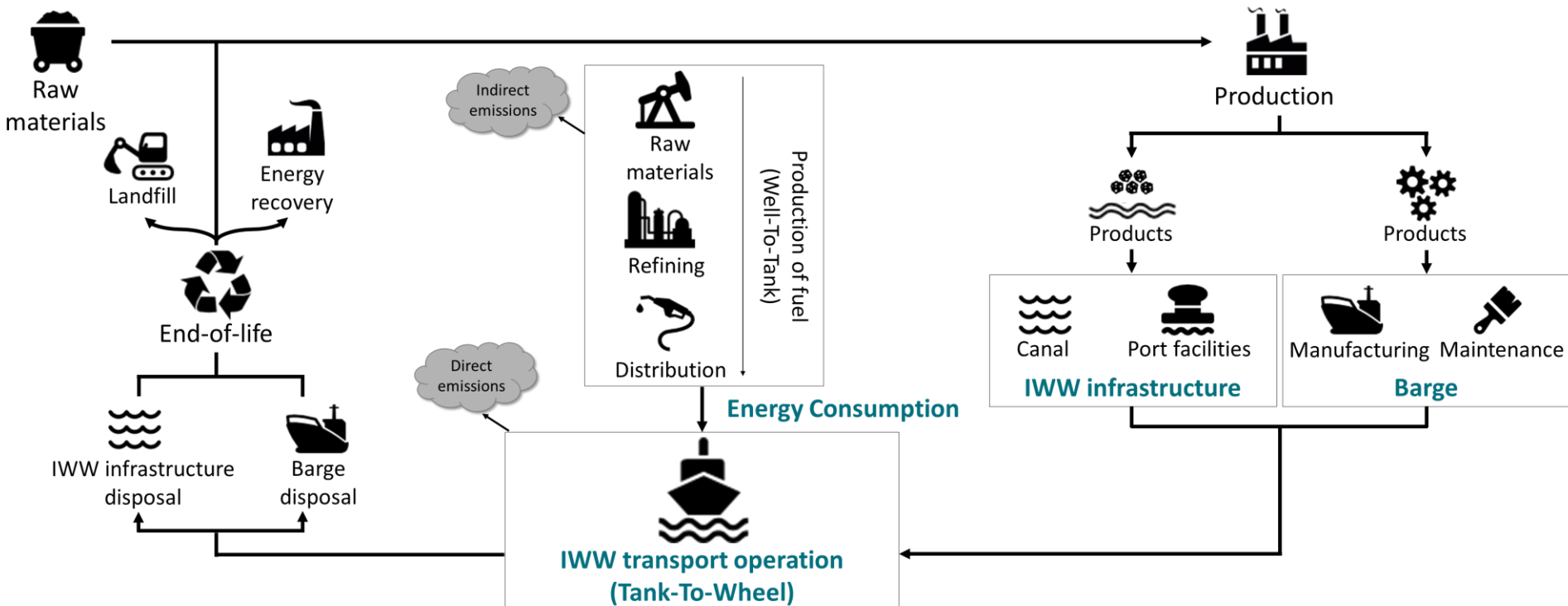


LCIA of 1 tkm transported by rail freight transport in 2012

■ {BE} Diesel trains
 ■ {BE} Electric trains
 ■ {DE} Electric trains
■ {FR} Electric trains
 ■ {NL} Electric trains
 ■ {PL} Electric trains



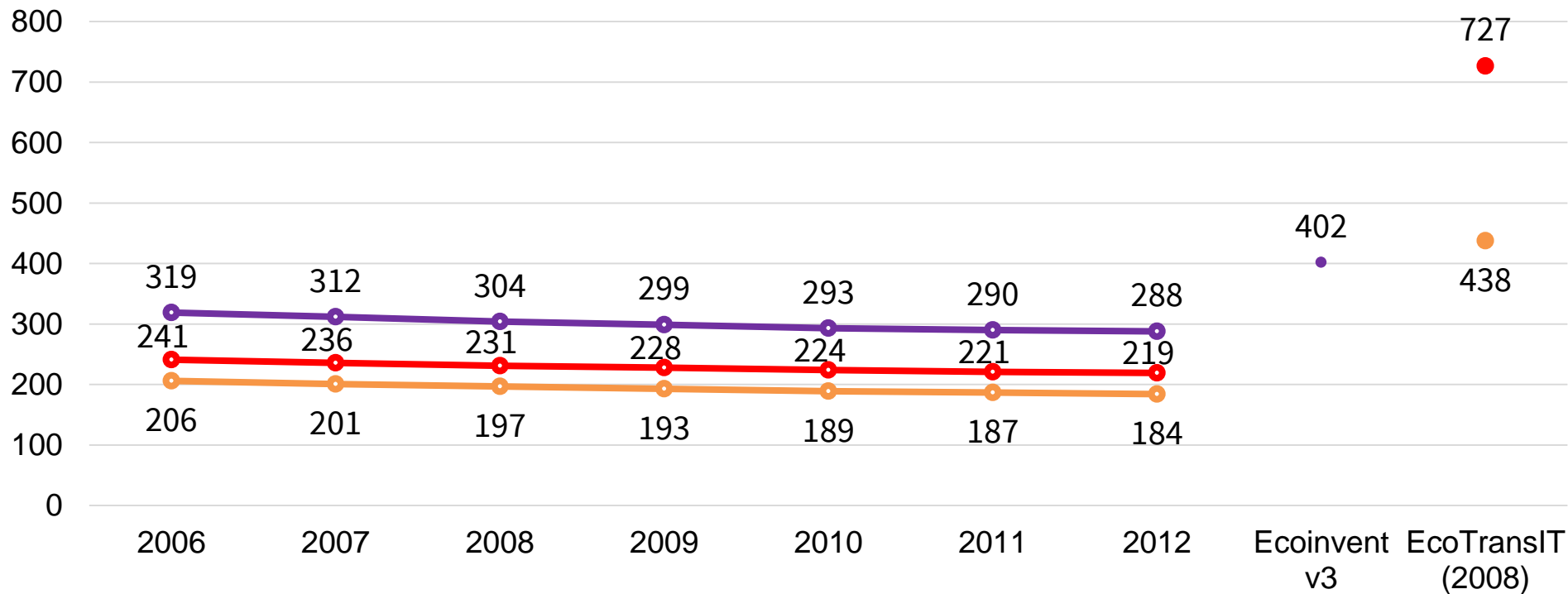
LCIA of IWW transport



IWW operation: Energy consumption

Energy consumption (kJ/tkm) of IWW transport

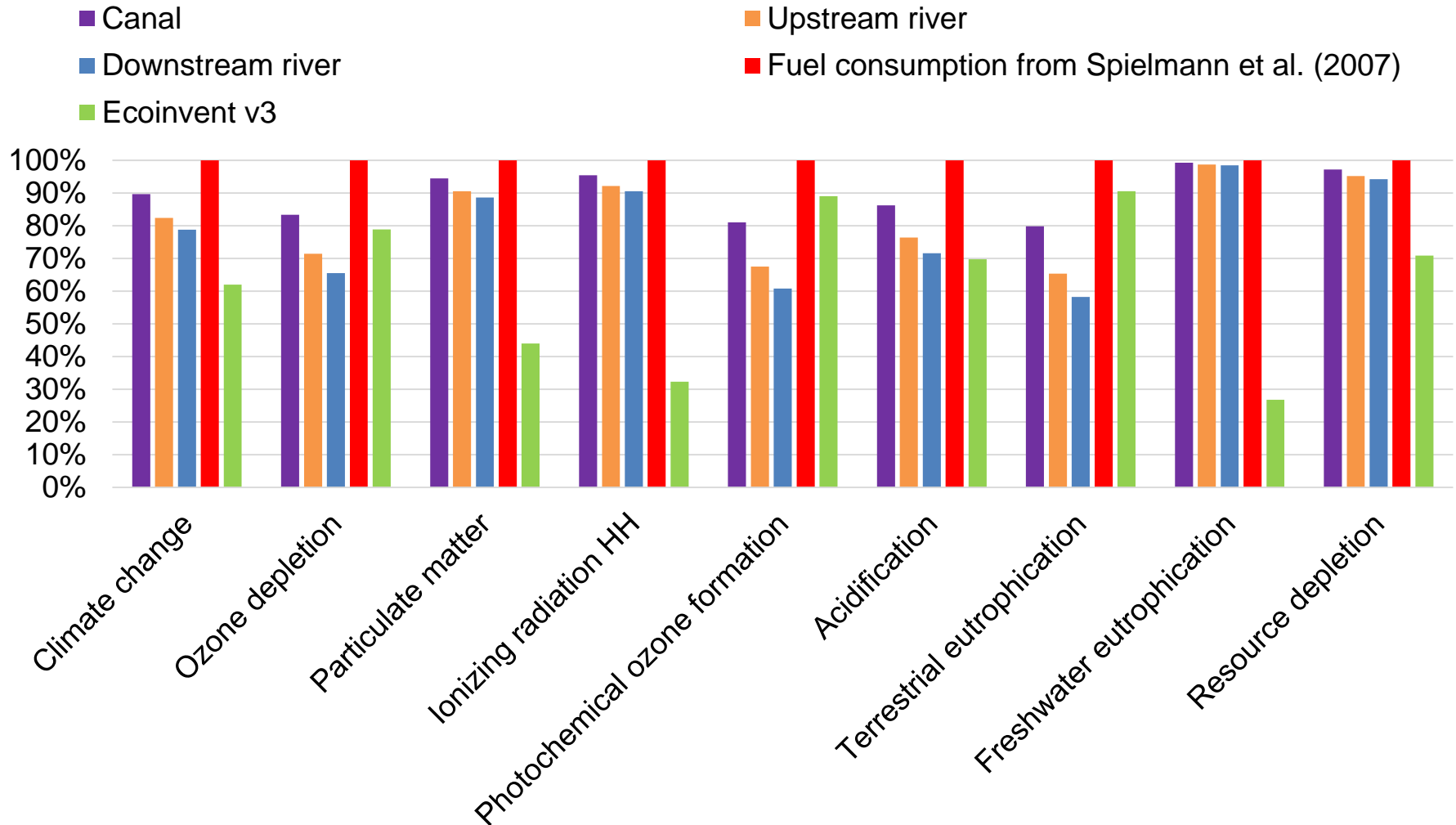
—●— Canals —●— River Upstream —●— River Downstream



► Exhaust emissions from barges

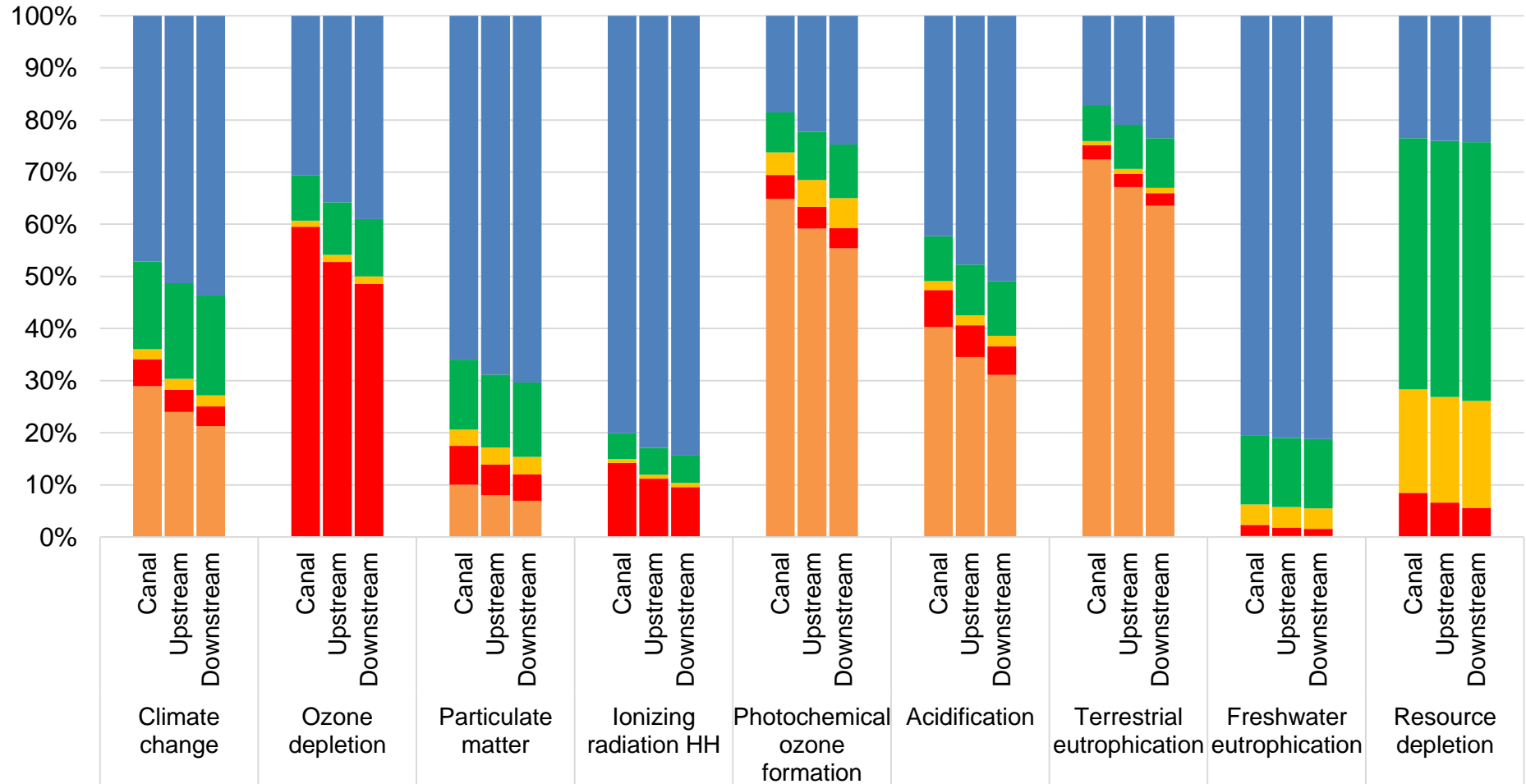
Exhaust emissions to air			
CO ₂	NMVOOC	PM	Methane
CO	NH ₃	PM _{2.5}	Toluene
NO _x	N ₂ O	PM ₁₀	Benzene
SO ₂	Benzo(a)pyrene	HCl	Xylene
Heavy metals (Cd, Cu, Cr, Ni, Se, Zn, Pb, Hg)			

LCIA of 1 tkm transported by IWW transport in Belgium in 2012

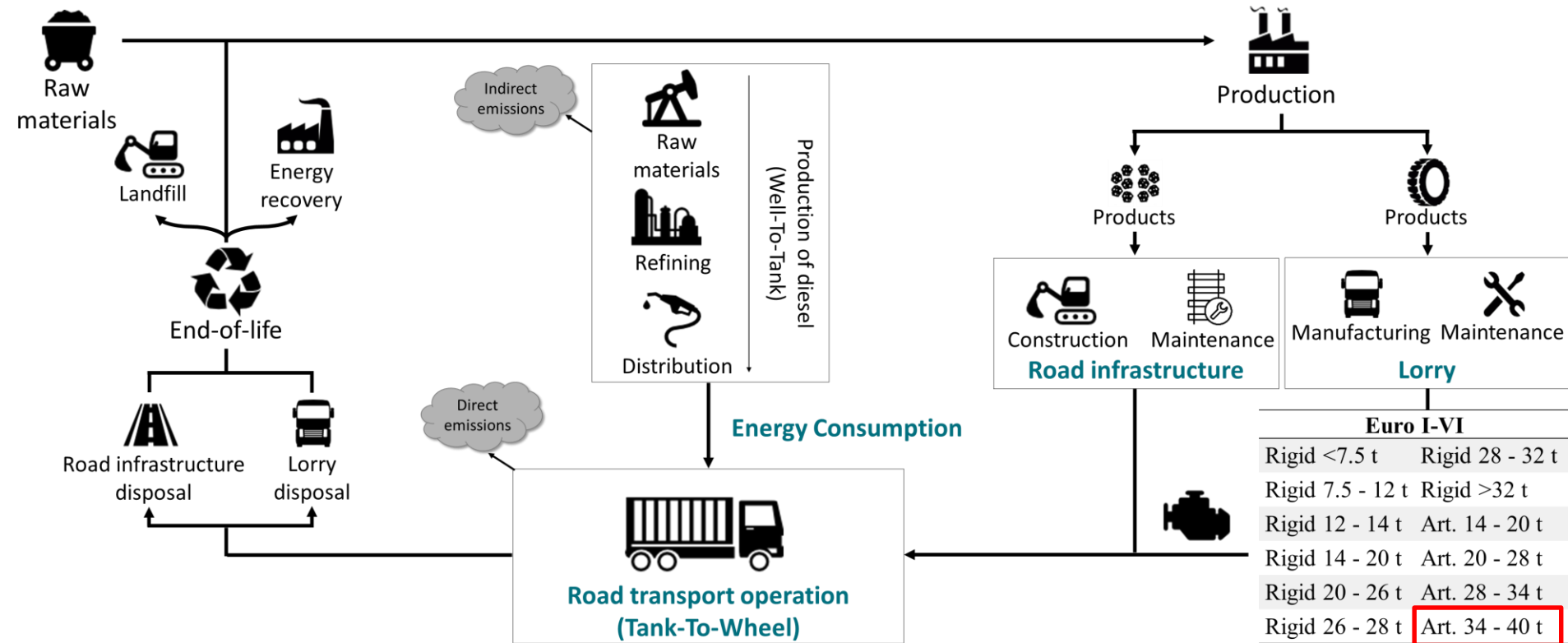


LCIA of 1 tkm of IWW transport in Belgium in 2012

■ Transport operation
 ■ Fuel
 ■ Vessel
 ■ Canal
 ■ Port



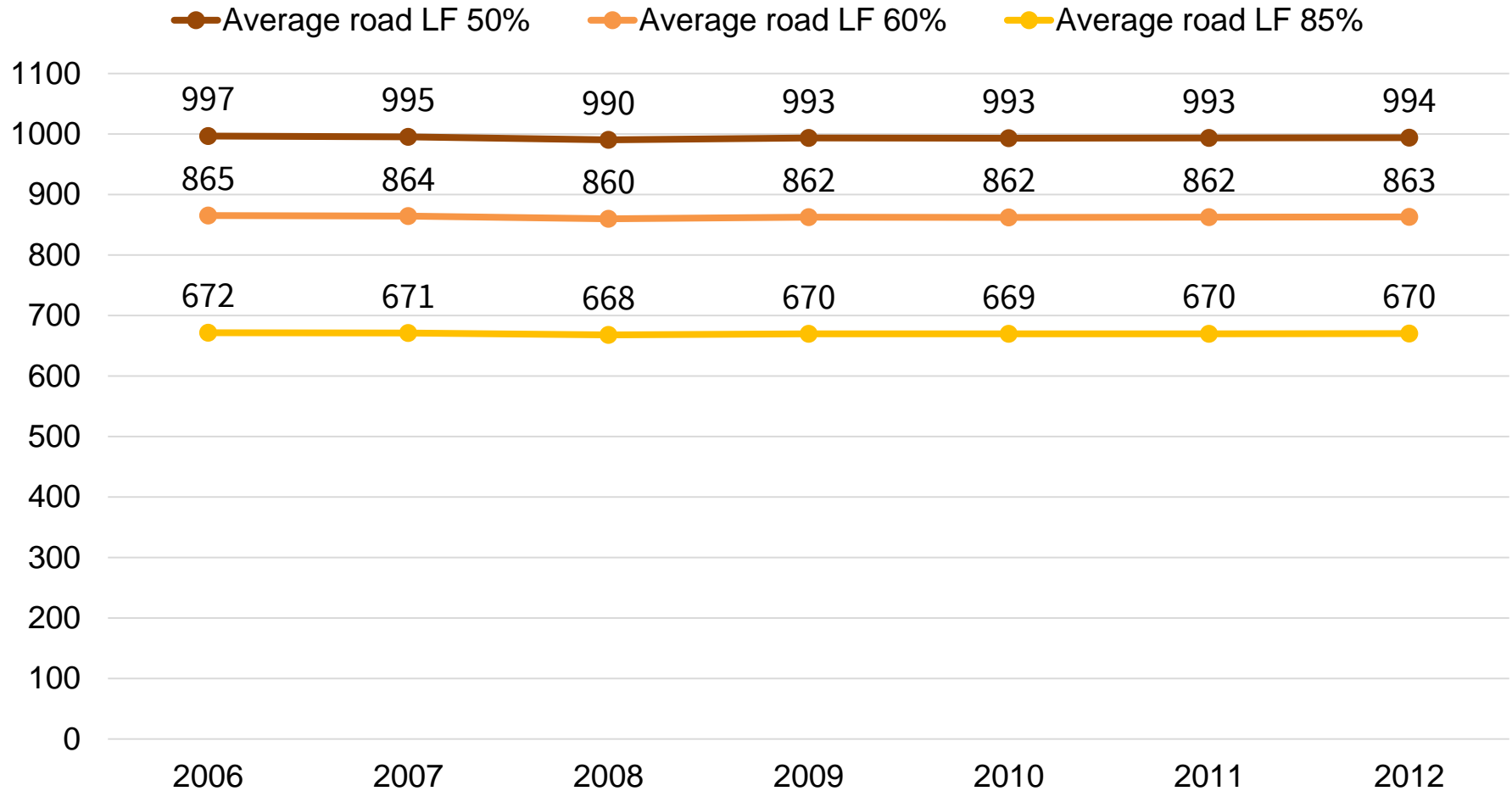
LCIA of road freight transport



- ▶ Load Factors (LF) of 50%, 60% and 85%
- ▶ Articulated lorry of 34-40 t represents $\approx 75\%$ of tkm of road transport every year in Belgium

Road operation: Energy consumption

Energy consumption (kJ/tkm) of road freight transport



Road operation: Direct emissions

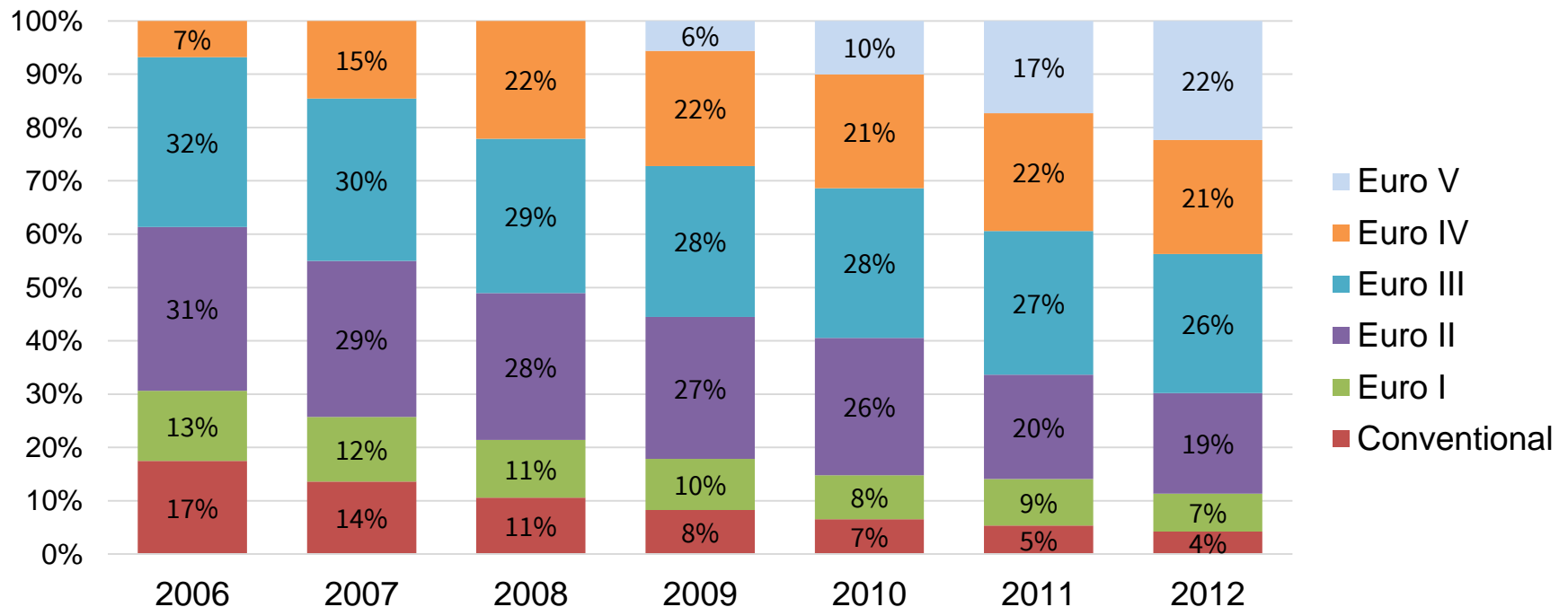
- ▶ Fuel dependent emissions (CO₂, SO₂ and Heavy metals)



- ▶ Emissions dependent on the engine emission technology (CO, NO_x, PM...)



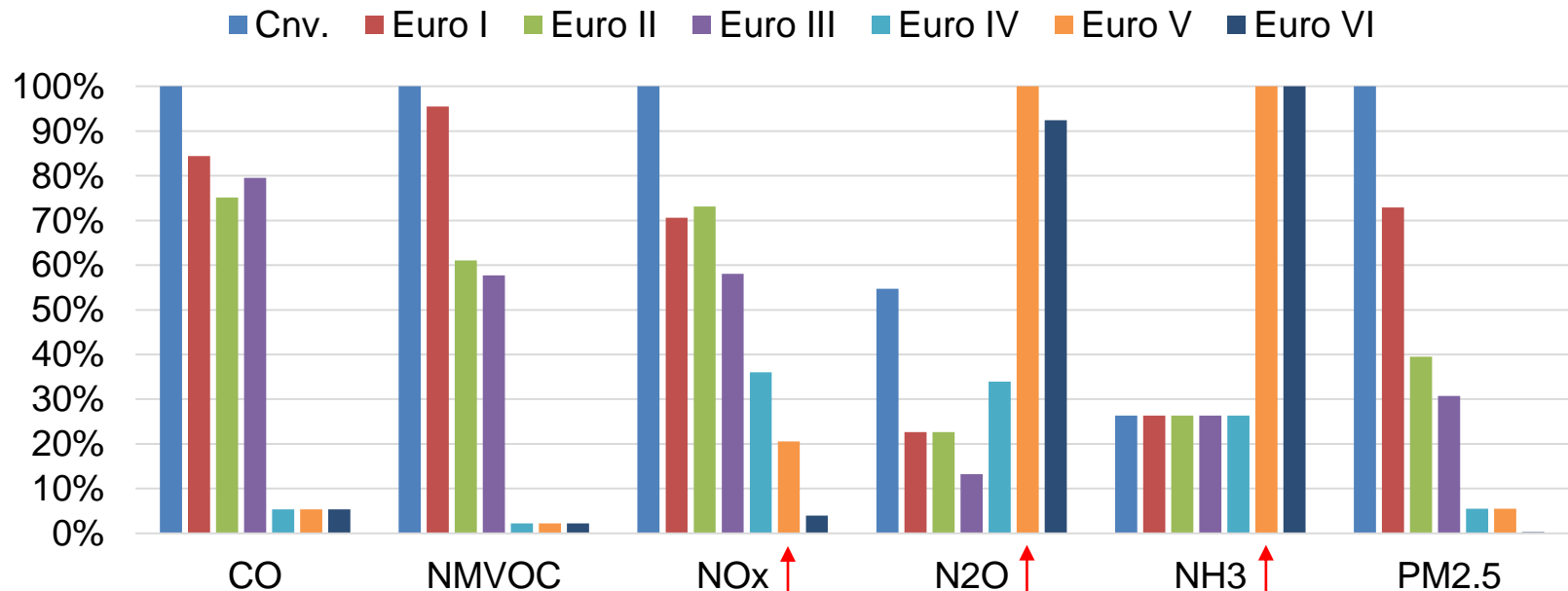
Lorry distribution by emission engine technology in Belgium



Road operation: Direct emissions

- ▶ Emission standards are different between lorry categories

Comparison emissions factors lorry > 32 t

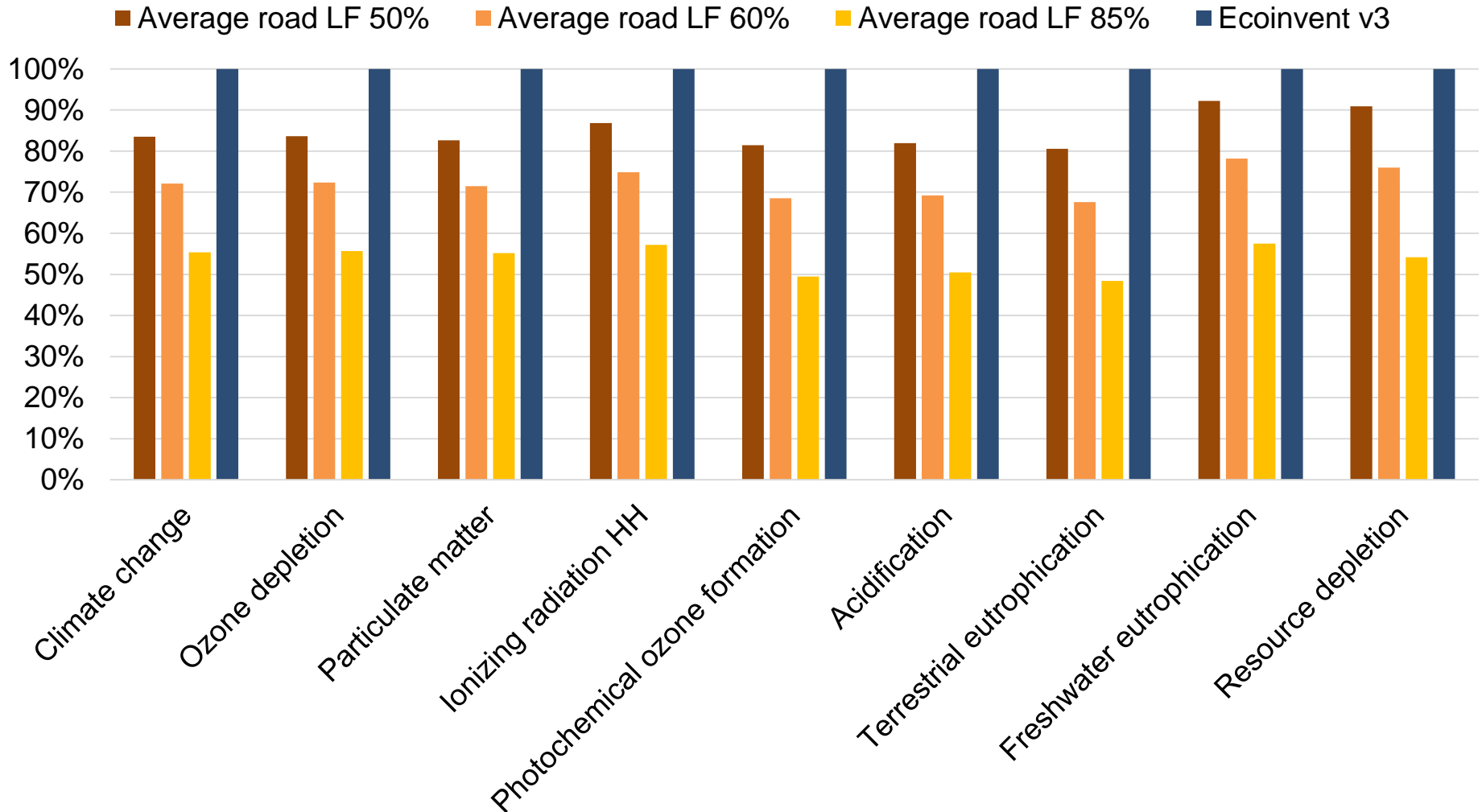


Selective Catalytic Reduction (SCR) systems to abate NO_x exhaust emissions

- ▶ Particle emissions resulting from road, tyre and brake wear

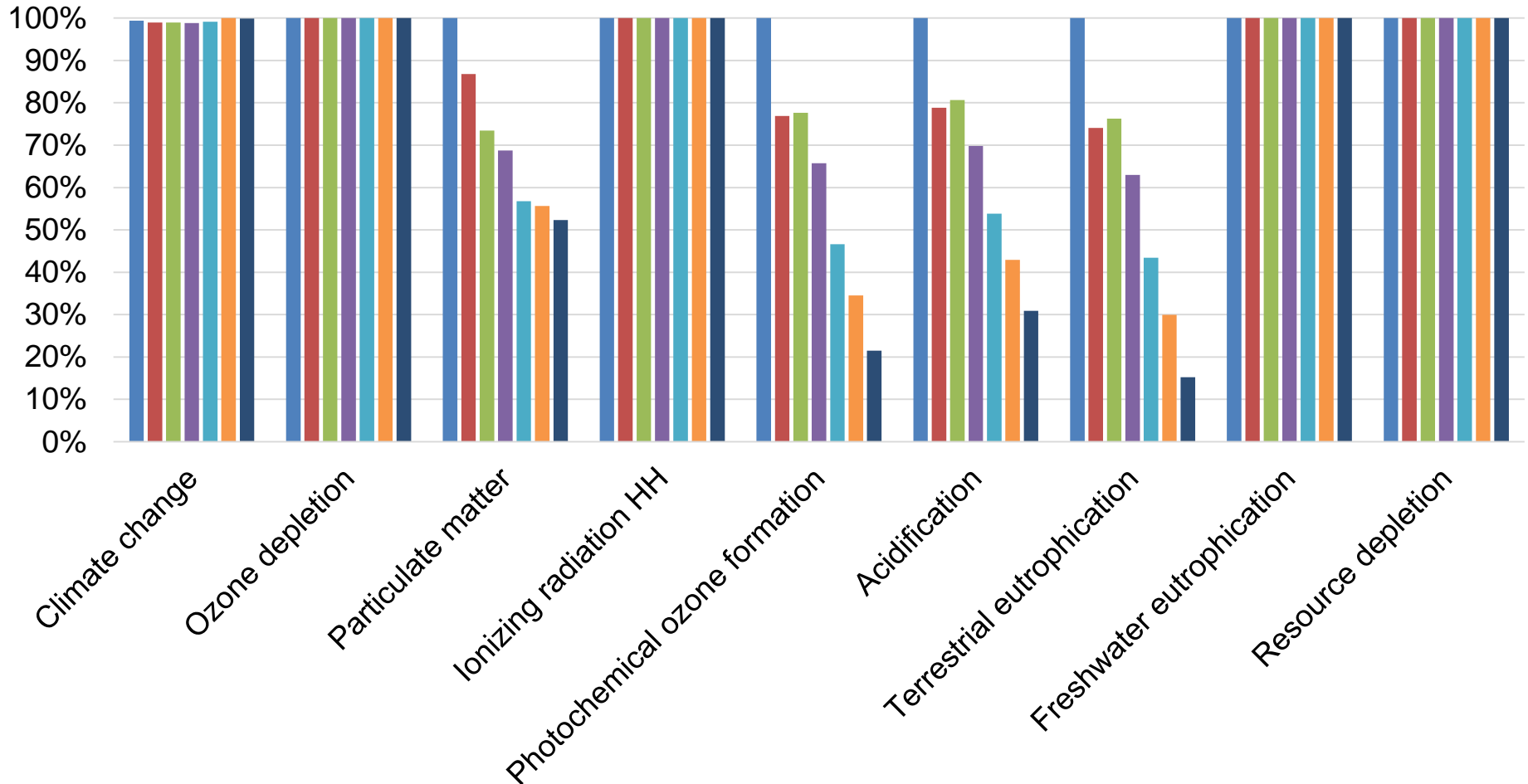


LCIA of 1 tkm transported by road in Belgium in 2012



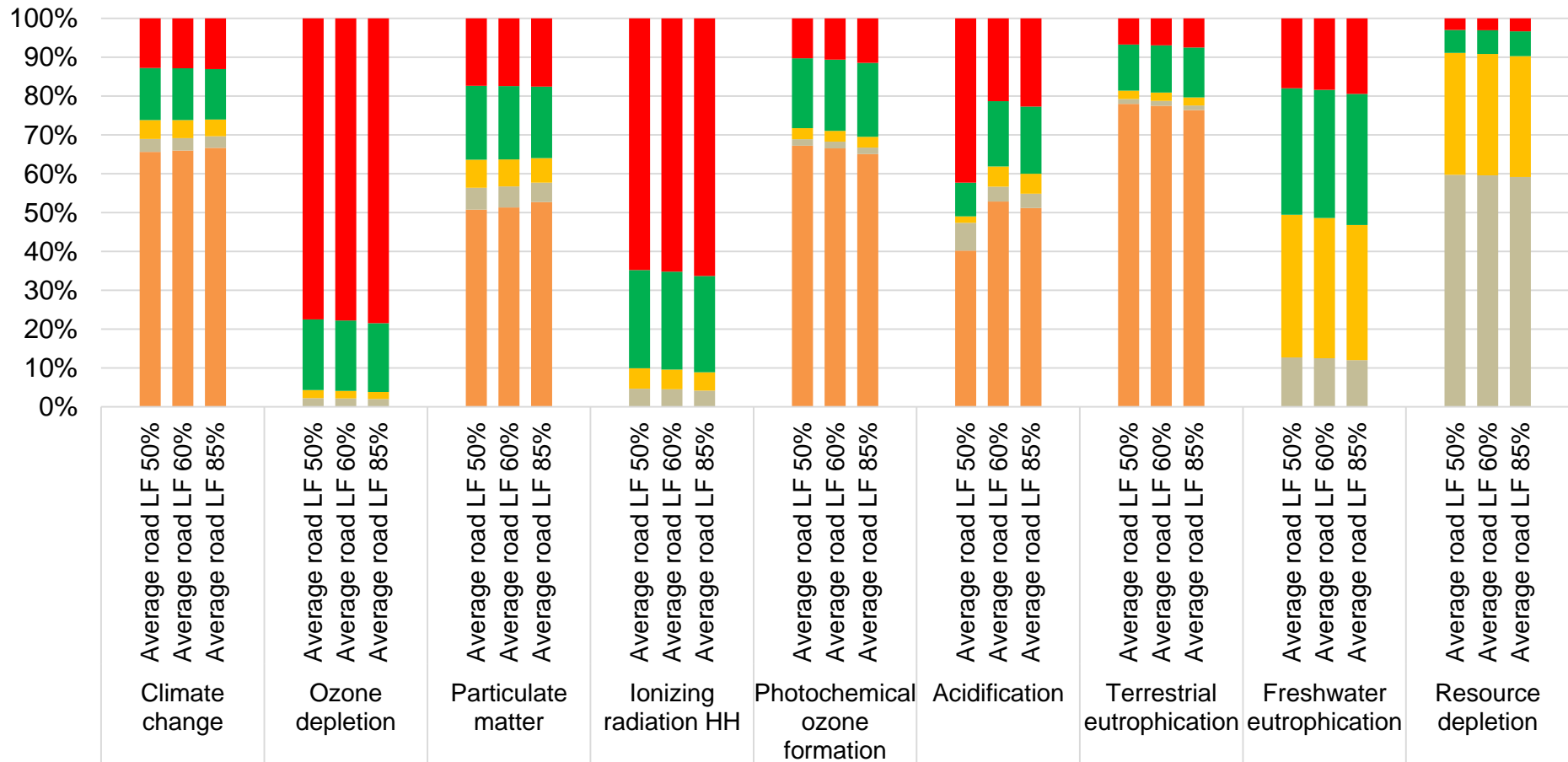
LCIA of 1 tkm transported by an art. lorry 34-40 t in Belgium in 2012

■ Conventional ■ Euro I ■ Euro II ■ Euro III ■ Euro IV ■ Euro V ■ Euro VI

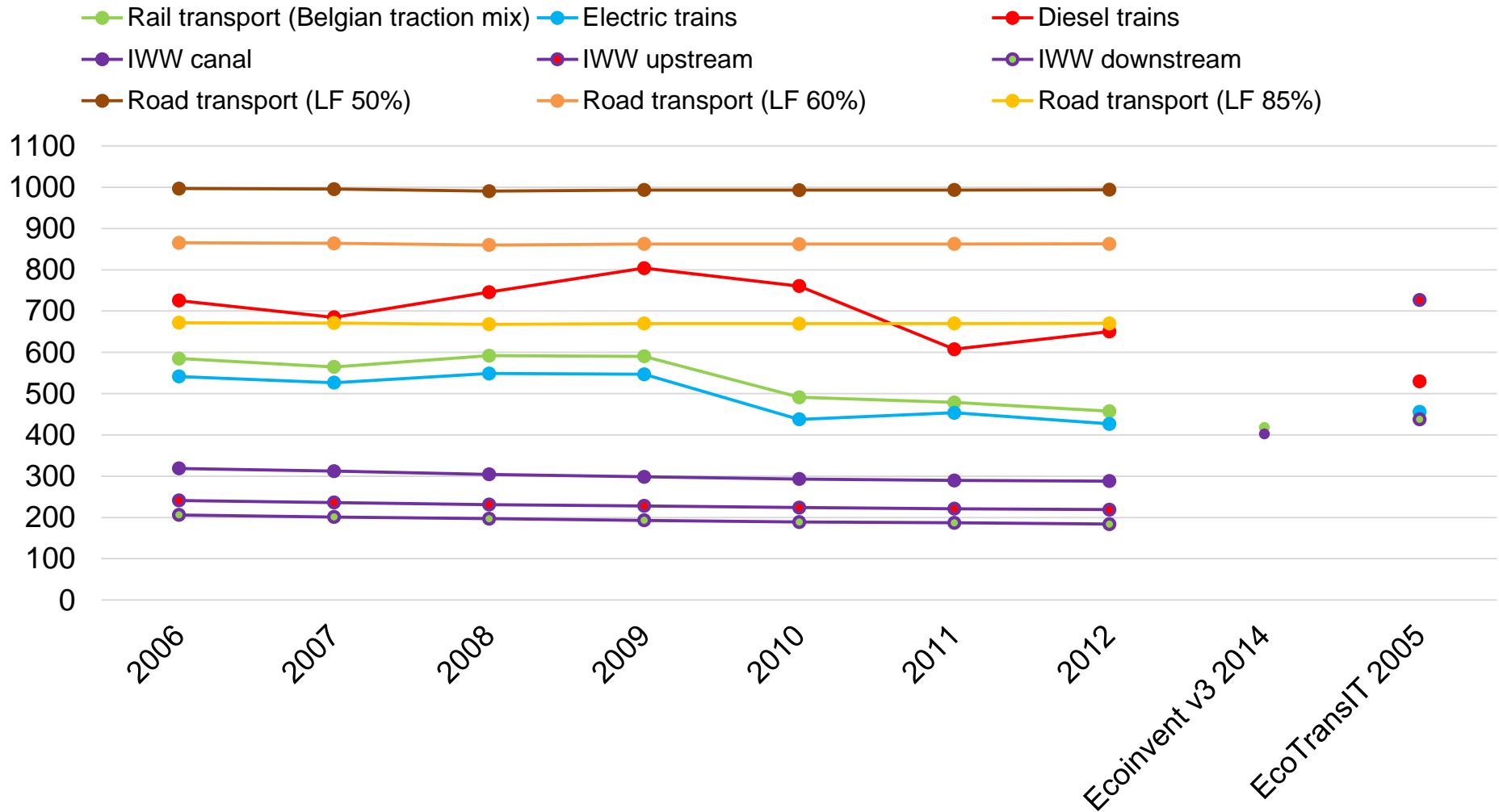


LCIA of 1 tkm transported by road in Belgium in 2012

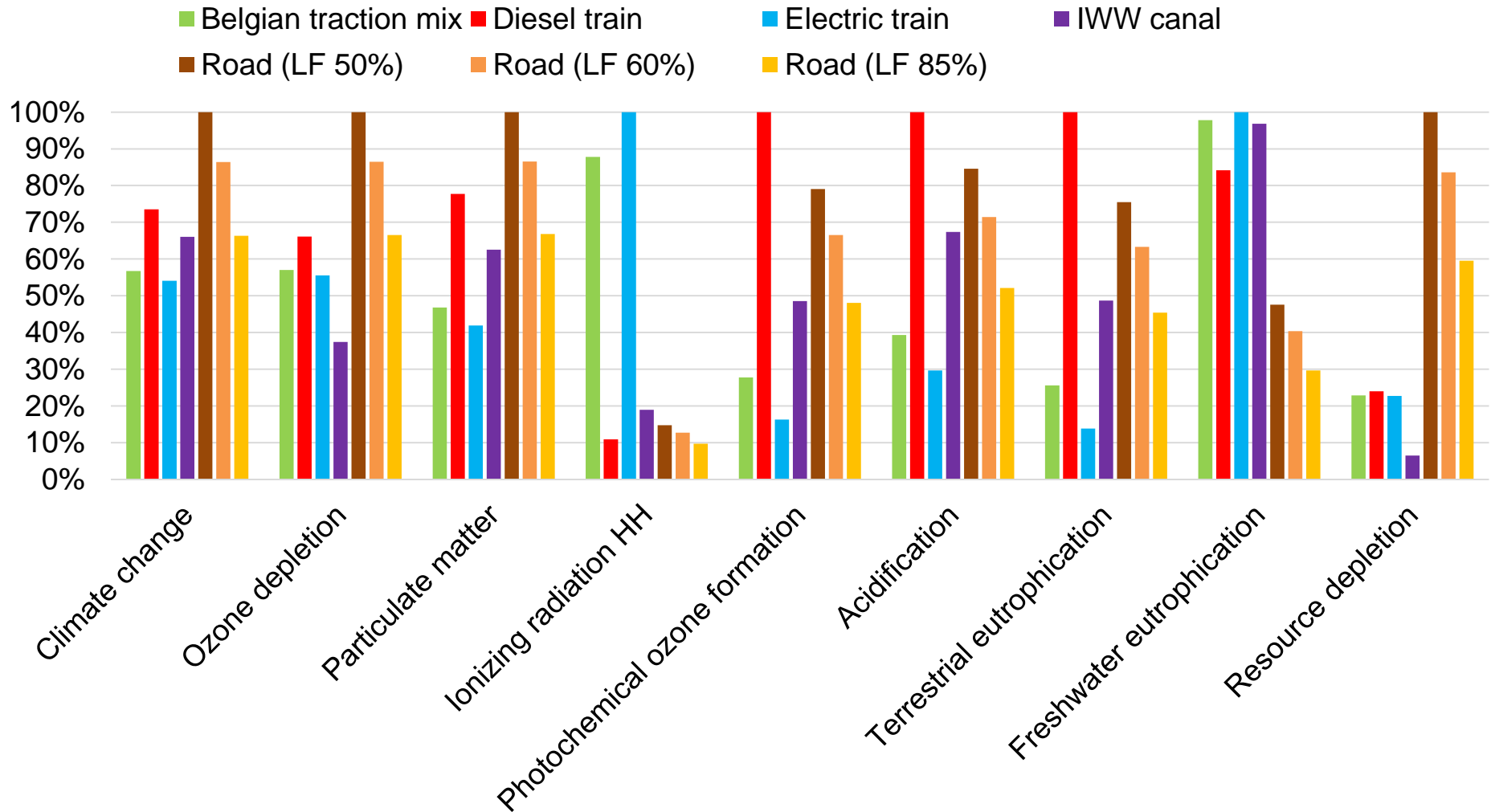
■ Transport operation
 ■ Maintenance lorry
 ■ Lorry
 ■ Road
 ■ Diesel



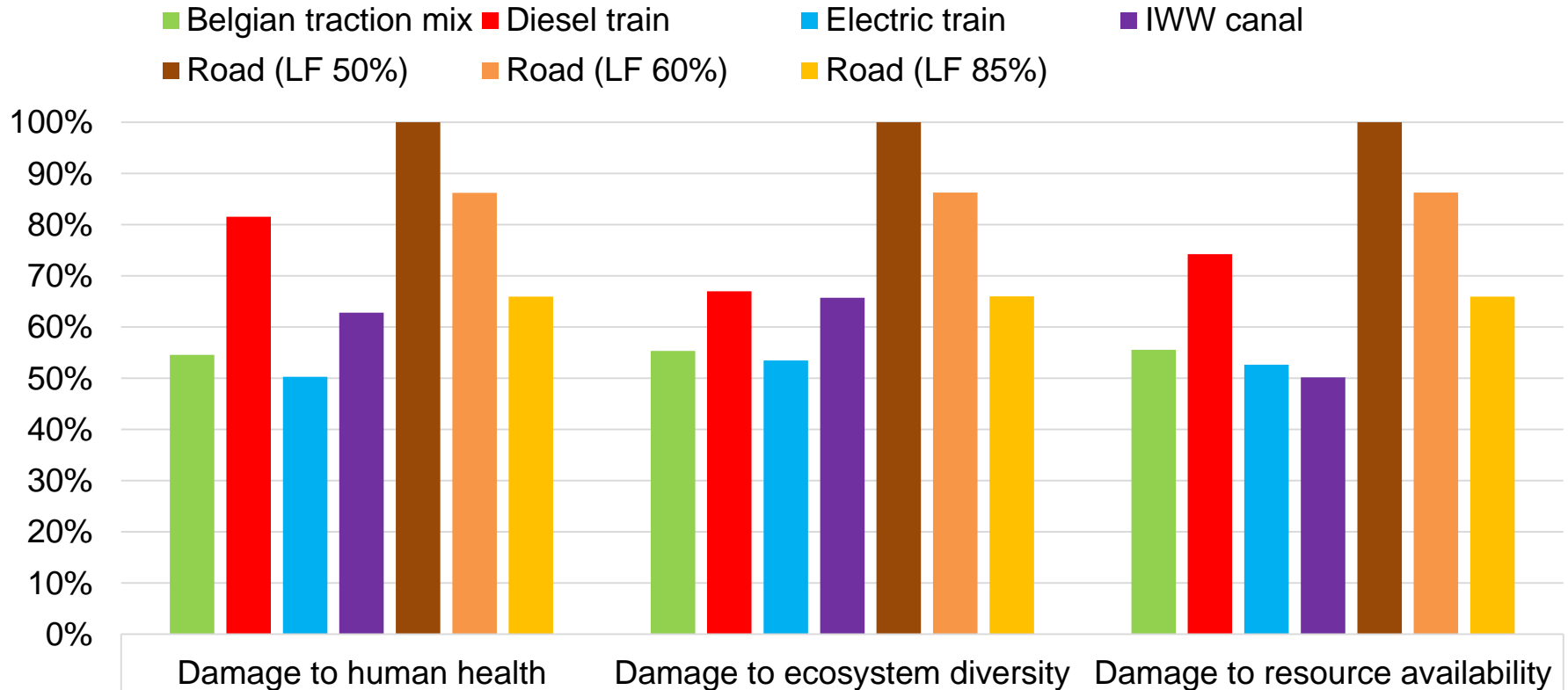
Energy consumption (kJ/tkm) of inland freight transport in Belgium



LCIA of 1 tkm by inland freight transport in Belgium in 2012

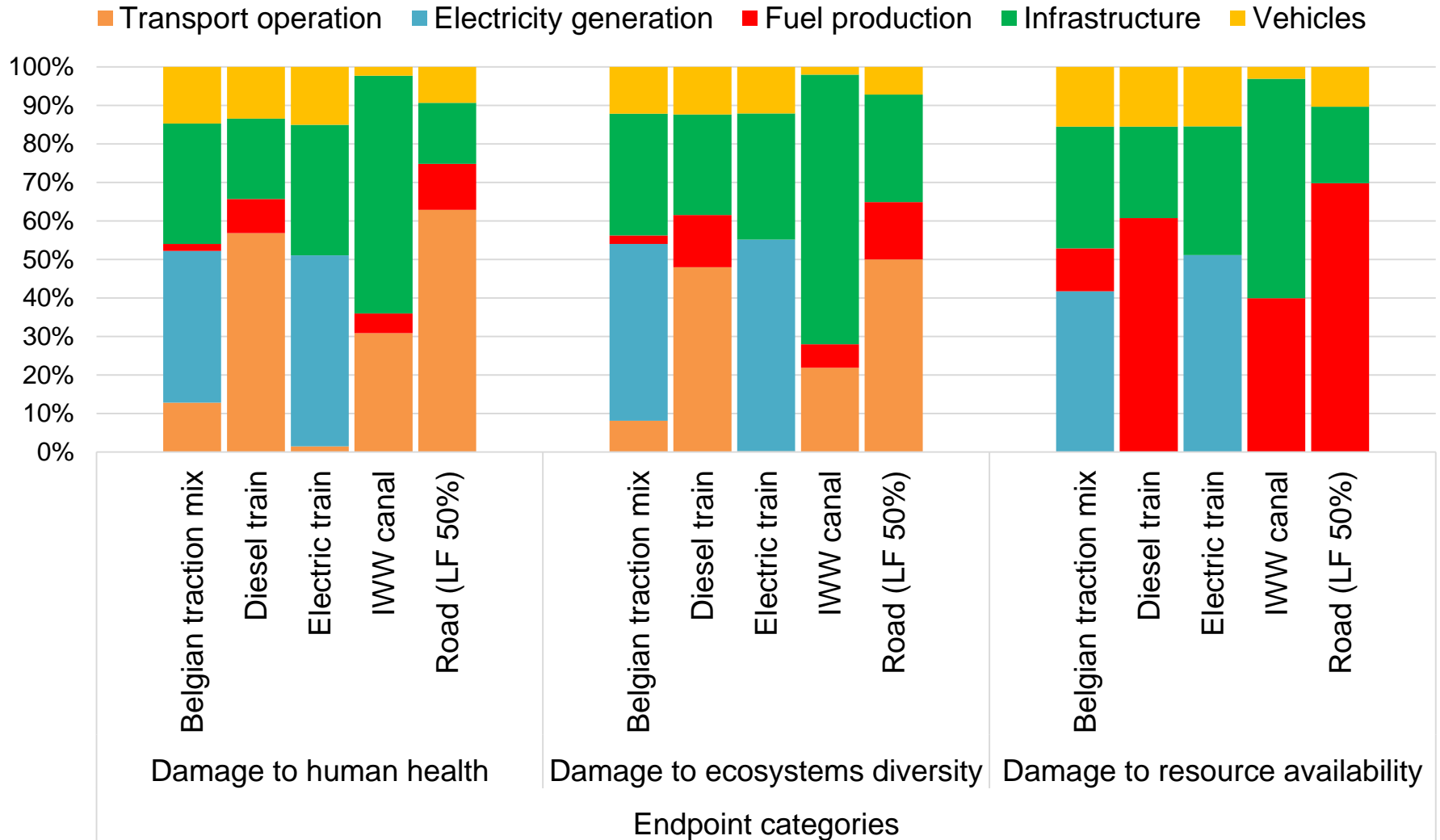


LCIA of 1 tkm by inland freight transport in Belgium in 2012



- ▶ These results have been published in:
- ▶ Merchan, A.L, Léonard, A., Limbourg, S., Mostert, M., “Life cycle externalities versus external costs: The case of inland freight transport in Belgium”, Transportation Research Part D: Transport and Environment, Vol. 67, pp. 576 – 595, 2019. <https://doi.org/10.1016/j.trd.2019.01.017>

LCIA of 1 tkm by inland freight transport in Belgium in 2012



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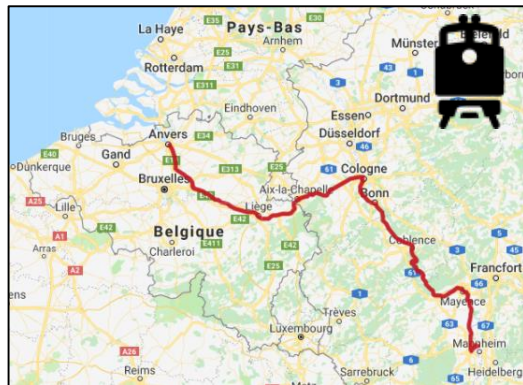
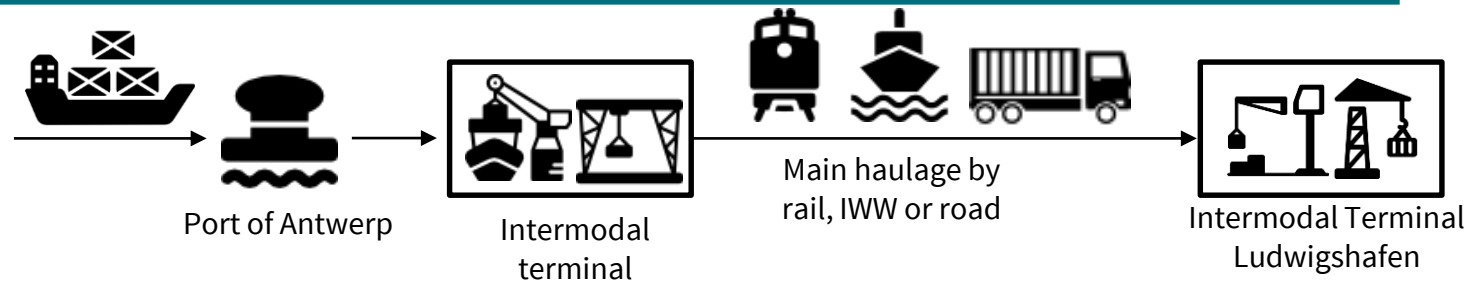
8. Study of the modal split of inland freight transport in Belgium



IV. Conclusions and perspectives

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Intermodal route Port of Antwerp - Ludwigshafen

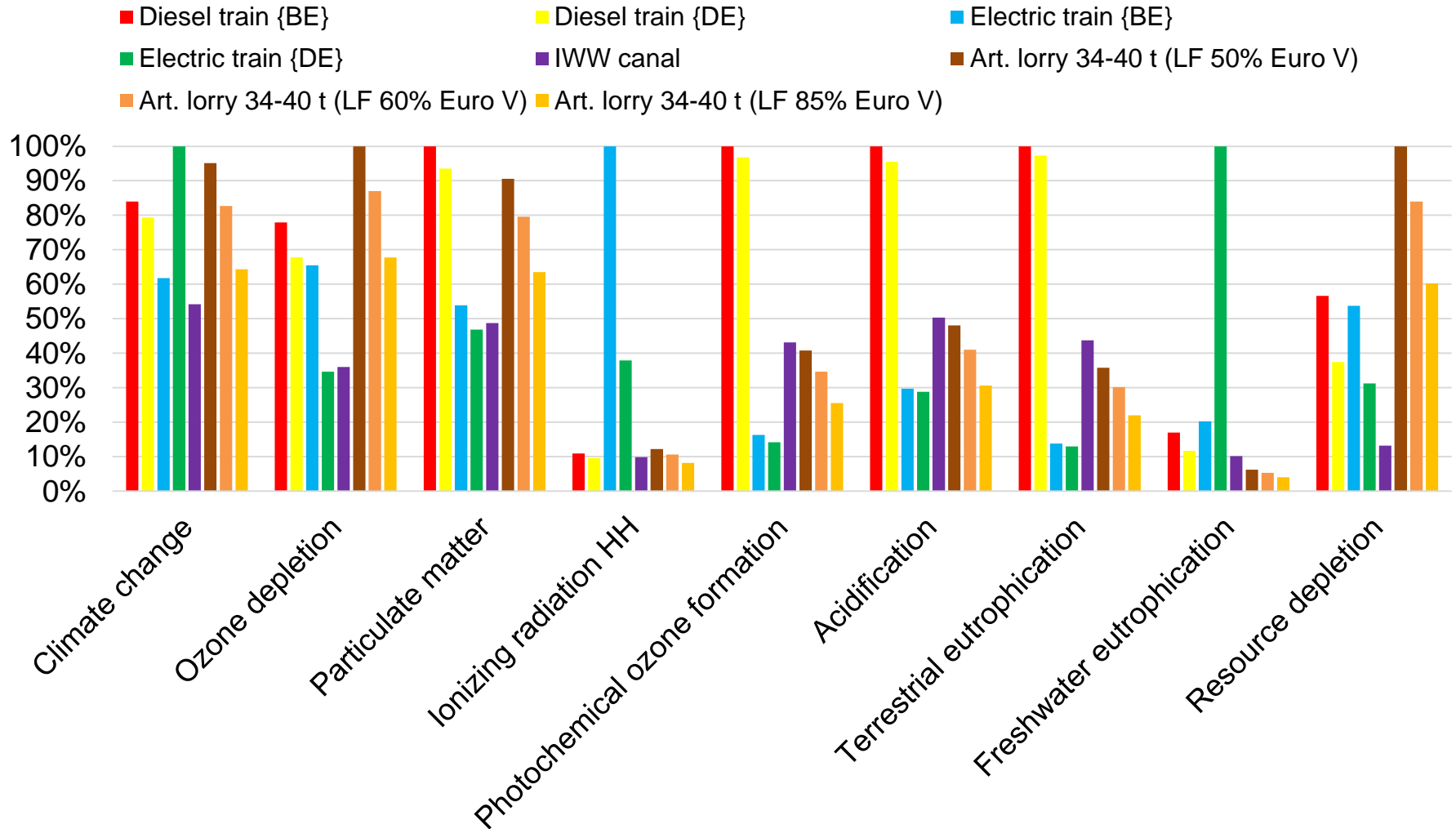


		Train	Barge	Lorry
Average gross weight TEU ¹		14.3 t/TEU		
1. Transhipment in the Port of Antwerp ²		16,560 kJ/TEU		
2. Main haulage	Max. payload (TEU/vehicle)	78	200	2
	Load factor	75%	60%	50% - 60% - 85%
	Distance (km) ³	488	621	407
3. Transhipment in Ludwigshafen ²		16,560 kJ/TEU		

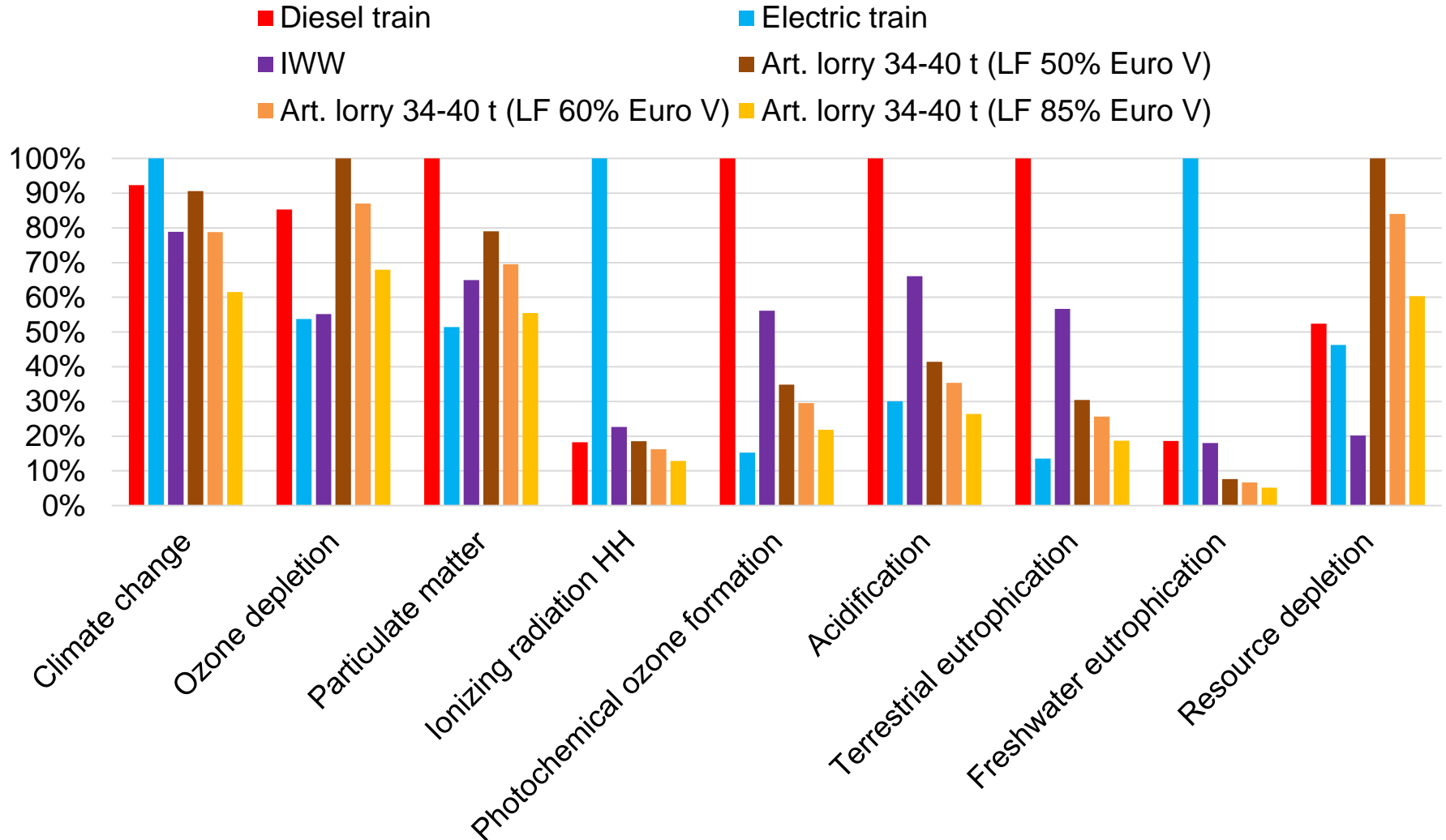
¹Janic (2008); ²Messagie et al. (2014); ³EcoTransIT World

LCIA of 1 tkm of freight transport in 2012

LCIA of 1 tkm by inland freight transport in Belgium {BE} and Germany {DE} in 2012



LCIA of the intermodal route Port of Antwerp - Ludwigshafen



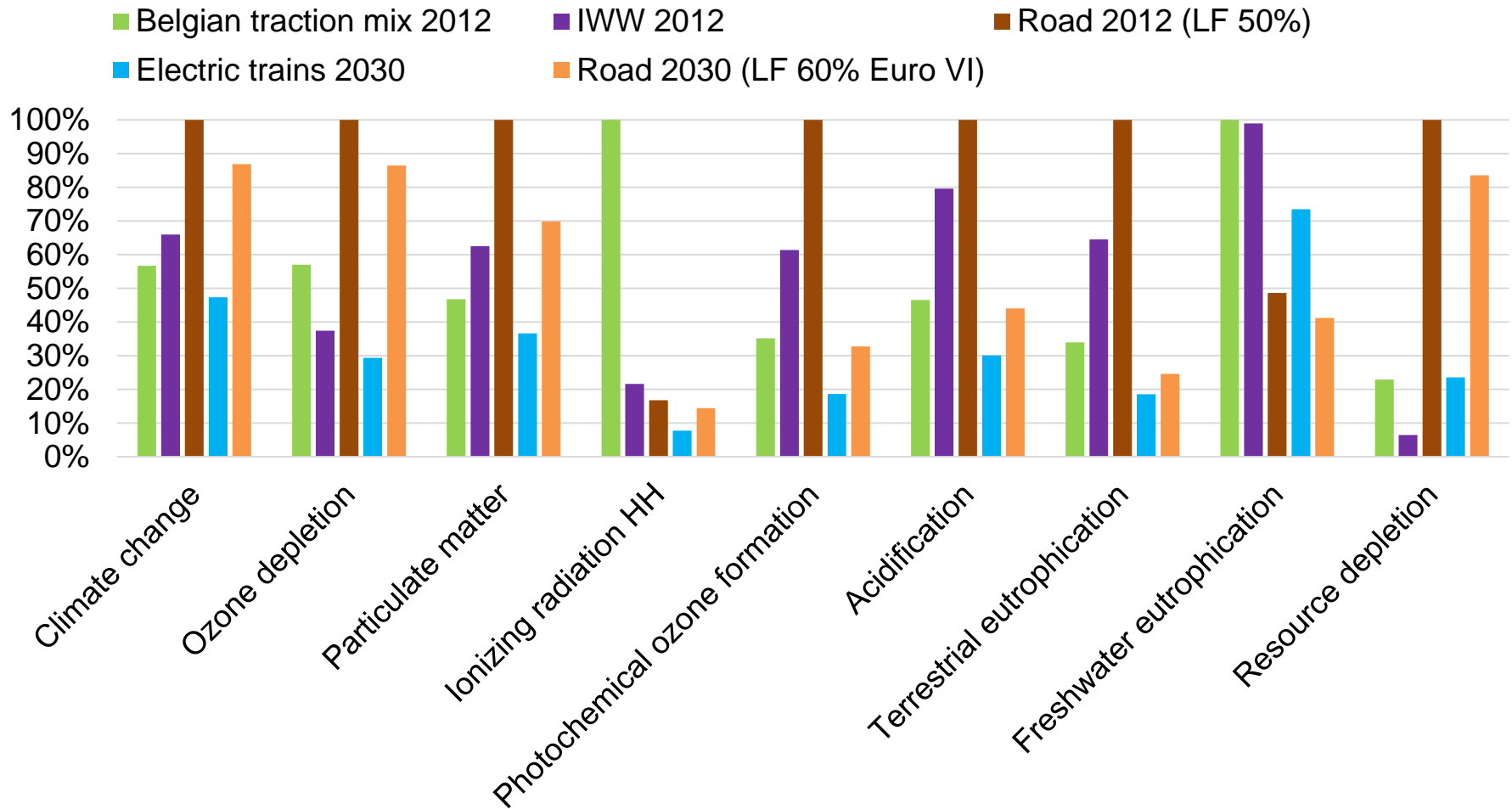
- Scenarios obtained for the optimization of operational costs
 - Intermodal allocation model developed by Mostert, Caris, and Limbourg (2017, 2018)

	Year 2012	Optimization of operational costs			
		Reference scenario	Best-case in 2030	Medium-case in 2030	Worst-case in 2030
Rail	14.6%	23%	30%	23%	13%
IWW	20.9%	4%	6%	4%	1%
Road	64.5%	73%	64%	73%	86%

Modal split of inland freight transport

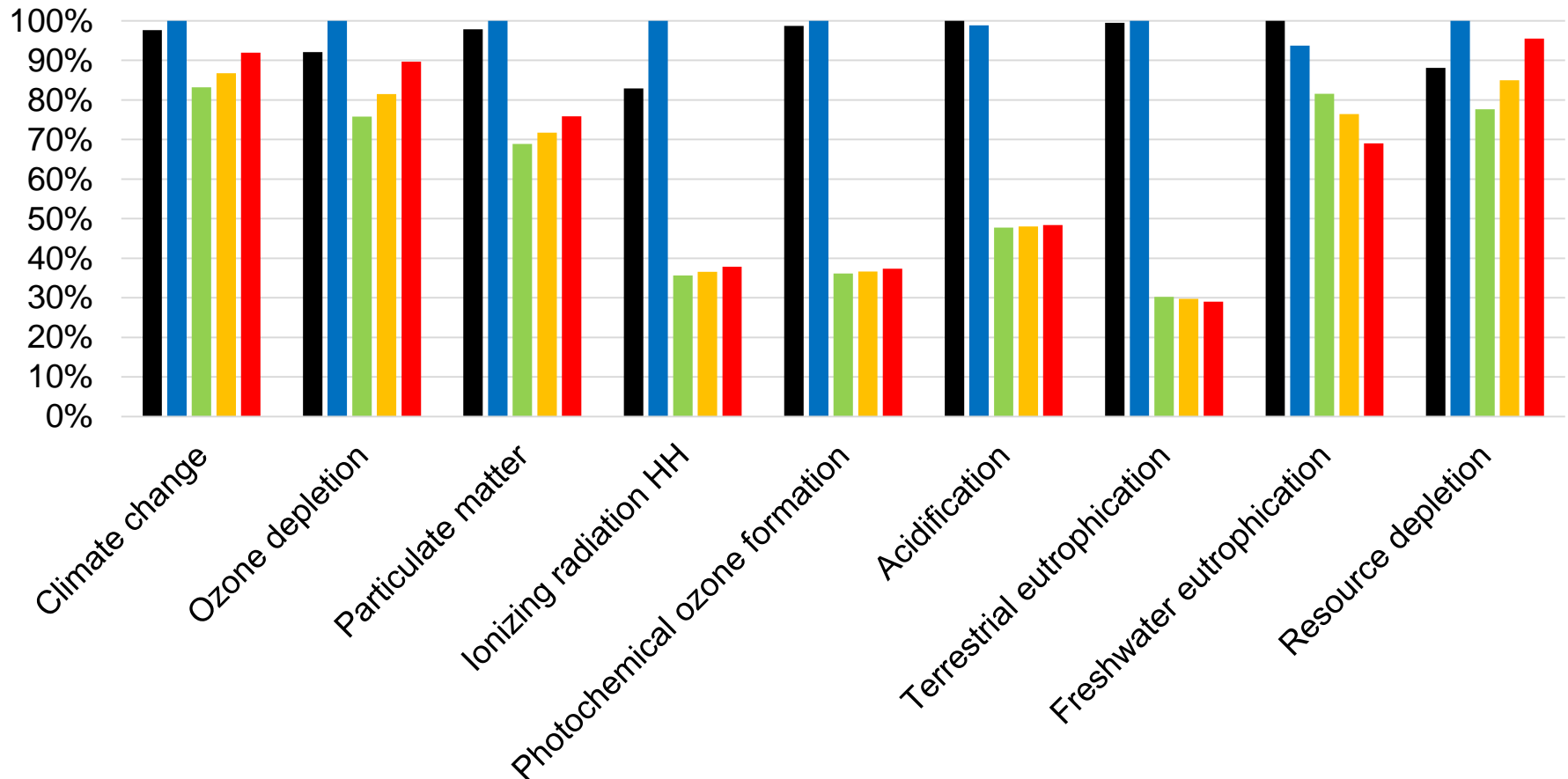
- **Electricity 2030:** Targets for CO₂ emissions reduction achieved and no nuclear power

LCIA of 1 tkm of freight transport



LCIA of 1 tkm modal split for the optimization of operation costs

■ Modal split 2012
 ■ Reference scenario
 ■ Best-case scenario
■ Medium-case scenario
 ■ Worst-case scenario



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IV. Conclusions and perspectives

9. Conclusions and perspectives

- ▶ Detailed study of rail freight transport in Belgium
 - ▶ Regionalisation of LCA results
 - ▶ Improvement of the existing LCA commercial databases
 - ▶ Increase of the share of electric trains in the Belgian traction mix
 - ▶ Enhancement of the electricity used by electric trains
 - ▶ Increase of the load factors and energy efficiency
 - ▶ Improvement of the emission technology of the vehicles
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- ▶ Update and improvement of the considered data
 - ▶ Lack of available data
 - ▶ Time period from 2006 to 2012
- ▶ Enhancement of the LCA methodology
 - ▶ Environmental impact indicators: accidents damage or noise
- ▶ Extensions of some parts of this thesis
 - ▶ Study other countries
 - ▶ Other intermodal routes
 - ▶ Intermodal terminals and ports

Thank you for your attention.

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