EU Transport GHG: Routes to 2050 II

The role of GHG emissions from infrastructure construction, vehicle manufacturing, and ELVs in overall transport sector emissions

Presentation by Charlotte Brannigan (AEA)

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Partners

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Overview

- Introduction to Task 2
- General information/emission factors
- Infrastructure
- Vehicle production and ELVs
- Next steps – reaching optimal solutions

Task 2 Introduction

- **Objective:** Development of a better understanding of the role of GHG emissions from infrastructure construction, vehicle manufacturing and end of life vehicles.

- **Outputs:**
  - Quantification of the typical GHG emissions associated with new road infrastructure, rail infrastructure, ports infrastructure and aviation/airports infrastructure.
  - Quantified assessment of the GHG emissions associated with vehicle manufacturing, taking into account the impacts of policies that might stimulate the use of new vehicle technologies.
  - Quantified assessment of the impacts of transport GHG reduction policies on emissions associated with vehicle disposal.
  - Identification of how an optimal solution may be achieved.

- **Partners involved:**
  - AEA (Lead), TNO, CE Delft

Task 2 ï Focus groups May 2011

- Work undertaken to date on Task 2 was presented at the Focus Group on 4th May 2011.

- Draft report circulated and can be accessed on the project website.

- Presentation also accessible from the website.

- Summary information presented here, including updates from the draft report, and next steps.

General information / emission factors

Future Evolution in Energy and Material Production Emission Factors

- A number of information elements are common to the analysis of impacts across modes for infrastructure and vehicles:
  - Current + likely future development of the GHG intensity of fuels/energy carriers
  - Current + likely future development of GHG emission factors for the production of materials (/components) used in the construction of vehicles and infrastructure
- Summary set of default GHG emission factors identified to be used to help normalise analysis where possible (and % recycling rates).
- Literature review has shown significant reductions in GHG intensity are expected for key materials/components.
- Assumptions based on this were developed for the wider analysis:

Low GHG Pathway	% 2010 Total GHG emissions intensity, $kgCO_2e/kg$ material						Notes
	2010	2015	2020	2030	2040	2050	
Aluminum	100.0%	95.5%	88.0%	71.5%	53.4%	44.7%	
Cement/Concrete	100.0%	93.8%	87.5%	75.0%	62.5%	50.0%	
Li-ion batteries*	100.0%	91.7%	83.4%	66.8%	50.2%	33.6%	
Plastics	100.0%	96.3%	92.5%	85.0%	77.5%	70.0%	(1)
Steel	100.0%	93.8%	87.5%	75.0%	62.5%	50.0%	
Other materials	100.0%	96.9%	93.8%	87.5%	81.3%	75.0%	(2)

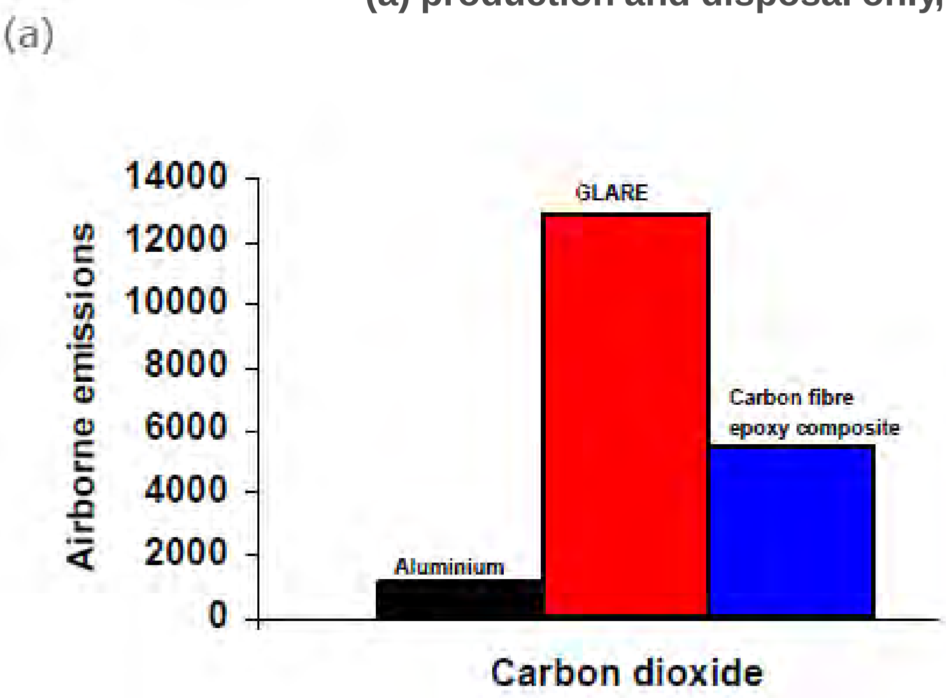
Notes: * or potentially substituted by an alternative battery technology depending on research developments
(1) Assumes 50% substitution with bioplastics, which achieve 60% improvement on conventional plastic alternatives by 2050
(2) Assumed nominal decrease on the basis of overall economy-wide pressure to reduce GHG emissions

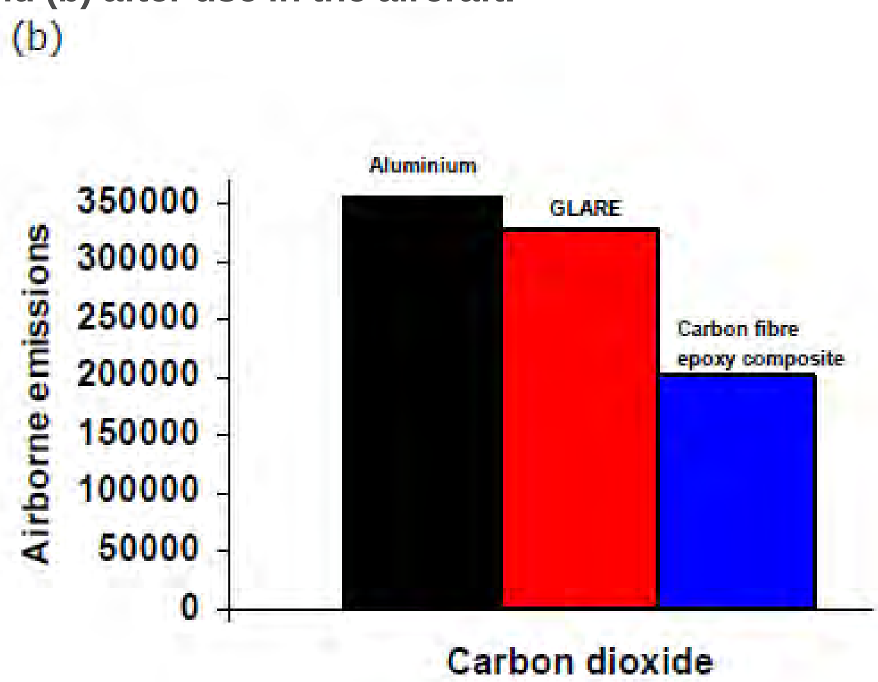
General information / emission factors

Impact of composite materials

- Increased use of composites has potential to significantly increase production emissions, but net benefits in total lifecycle, e.g. aircraft:
- Recycling options currently under investigation (reduce waste, GHG)

Comparison of airborne emissions of carbon dioxide
(a) production and disposal only, and (b) after use in the aircraft.





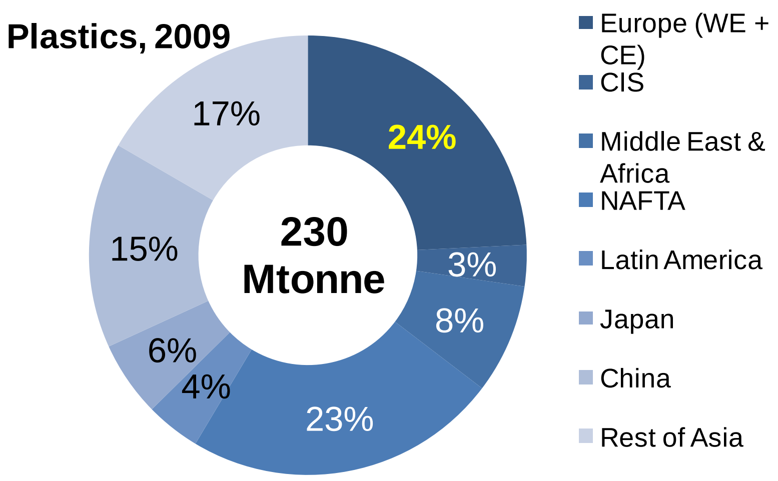
GLARE is a hybrid GLAss-REinforced fibre metal laminate

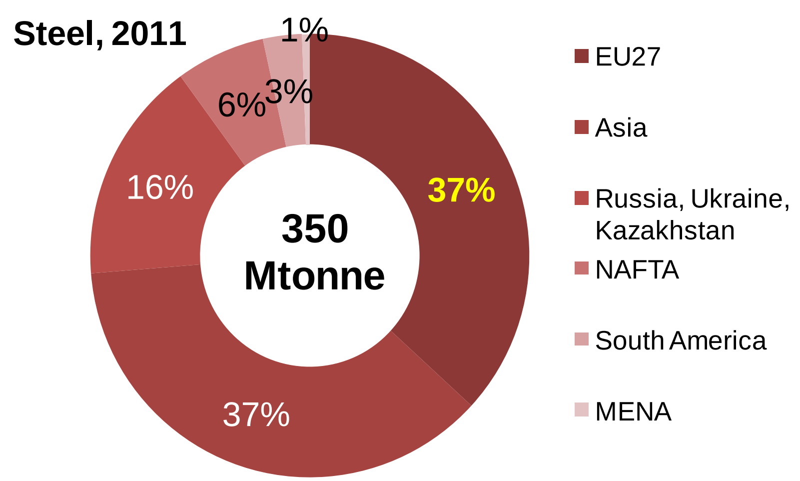
Source: OMEGA, 2010

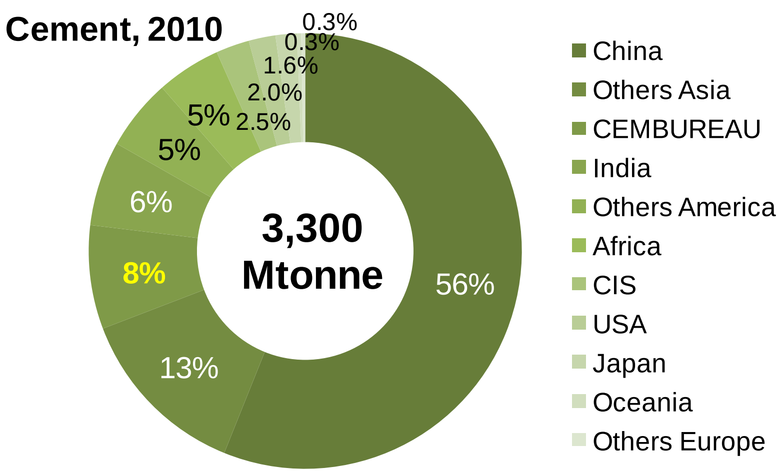
General information / emission factors

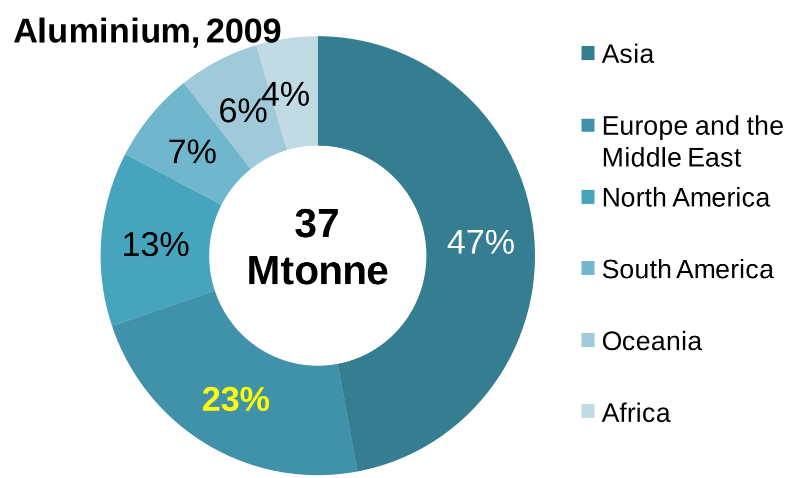
Sourcing of materials

- Sourcing of materials affects lifecycle GHG, current situation:









- CEMBUREU = EU 27 countries (excluding Cyprus, Malta and Slovakia) plus Norway, Switzerland and Turkey.

Infrastructure - Overview

- Considered the following modes:
  - Road;
  - Rail;
  - Aviation;
  - Shipping; and
  - Energy carriers.

- Included emissions from (where available):
  - Construction of infrastructure;
  - Maintenance of infrastructure; and
  - Operation of infrastructure (in-use)

Infrastructure - Road

- GHG emissions estimated to be between 10-40% of total depending on a range of factors, e.g. surface type, intensity of use, maintenance, lighting/elec mix, etc.
- Impacts greater for cars versus buses, coaches per passenger km.
- Maintenance and renewal estimated to be ~20% of initial construction emissions.
- Street lighting responsible for vast majority (>95%) of operating emissions, greatest for urban roads (high % lighting) versus motorways (low % lighting).
- GHG emissions from maintenance-related congestion and surface roughness estimated to be same order of magnitude as from construction/maintenance.
- Provision of new electric charging infrastructure may be ~5% lifecycle emissions for conventional petrol car (hydrogen infrastructure expected to be lower).

Infrastructure - Rail

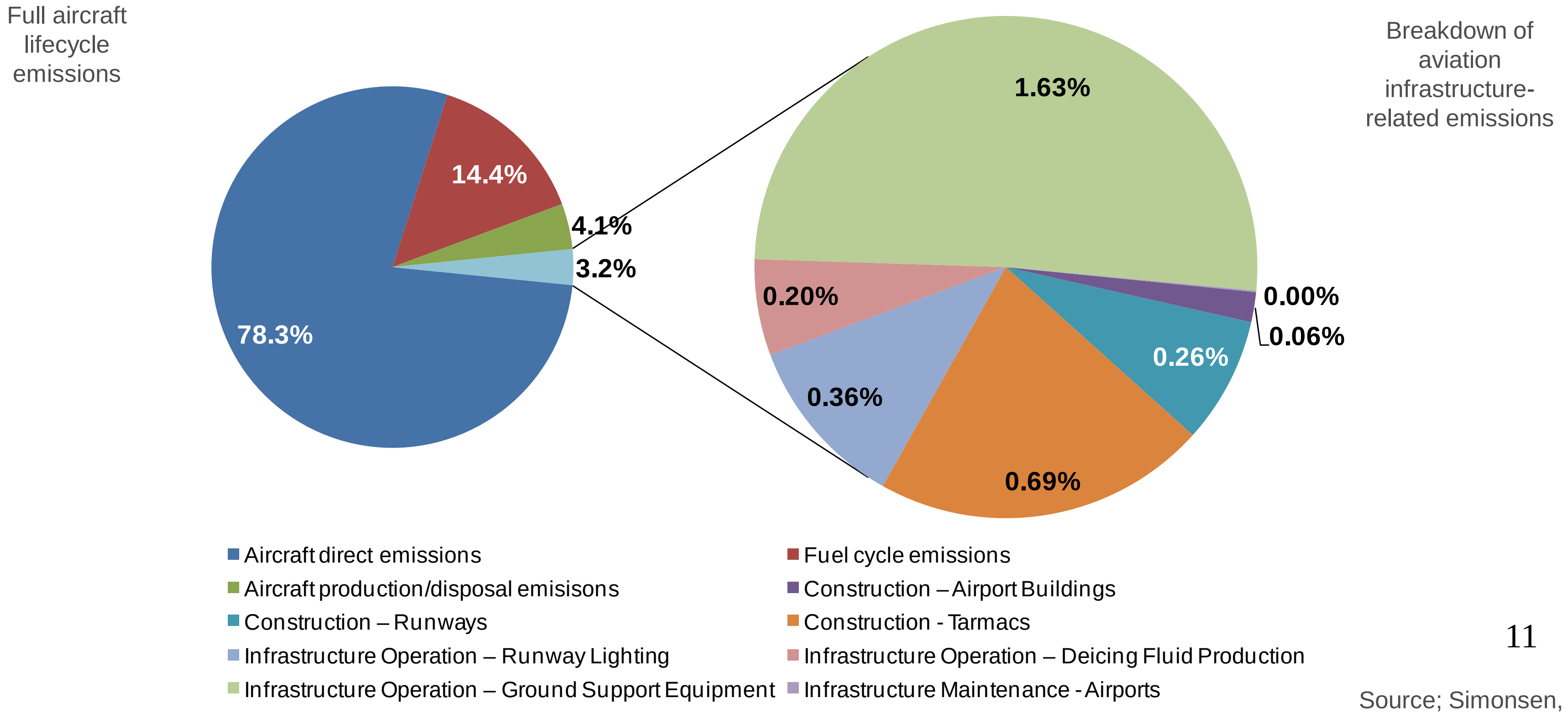
- Relative significance of infrastructure emissions is highly variable depending on a number of key factors:
  - Type of track: electrified or non-electrified track (i.e. for diesel rail), ballasted or ballastless track.
  - Share of tunnels and bridges in the total track length.
  - GHG intensity of energy used to power rolling stock (i.e. diesel, electricity).
  - Frequency of services / intensity of track utilisation (i.e. traffic level).
  - Passenger numbers / train % occupancy.

- Input material use comprises nearly 75% total construction emissions, or 53% total infrastructure construction emissions.

- *UIC (2009) Scenarios:* new rail infrastructure impacts ~9% - 85% total GHG, depending on (i) elec mix, (ii) % tunnels/bridges, (iii) traffic, (iv) % loading

Infrastructure - Aviation

- Aviation-related infrastructure can include airport terminals, runways/tarmacs and ground support equipment.
- Aircraft manufacturing GHG emissions estimates ~4-11% of total lifecycle (Chester and Horvarth, 2007)
- Infrastructure construction, maintenance and operation estimated at ~3%



Source; Simonsen, 2010

Infrastructure ï Shipping

- Shipping-related infrastructure may include docking area for ships, refuelling infrastructure, cargo storage, portside buildings and road/rail links.
- Few studies considering embedded emissions from port infrastructure, two principal studies identified show very significant differences:
  - Walnum (2011): infrastructure is ~0.01% lifecycle GHG emissions, port operations 15% and maintenance 0.01%.
  - Simonsen (2010): infrastructure between >0.01% and 0.05% of total ship lifecycle GHG emissions.
- Carbon footprints undertaken for a number of ports (Oslo, Rotterdam, Jurong) – identify operational emissions.
  - ~40% direct emissions from fuel use
  - ~40% indirect emissions resulting from electricity (lighting, buildings, equipment)
  - ~20% other indirect emissions (commuting and business travel)

Infrastructure ï Energy Carriers

- Hydrogen infrastructure:
  - Transported from production point to use point by pipeline, road, or by rail/barge
  - Pipelines – often made from stainless steel in order to resist damage via embrittlement. Polyethylene (PE) also used (also << embedded CO_2 vs steel).

- Biofuels infrastructure:
  - Refineries and production facilities; import facilities; pipelines; tank storage; tankers for transport of products (road, rail and coasters); retail forecourts; and on-site fuel depots (road freight, bus/coach operators, aviation, rail and shipping)
  - Road and rail – flexibility to transport mixture of blends, but limitations regarding the need to modify seals and linings of tankers.
  - Concern of technical ability of pipeline networks to carry biofuels – corrosive nature of biofuels, contamination of fuels being transported etc.
  - Retail forecourts – important link in the biofuels chain. Infrastructure is largely existing, with some need for modifications.

- Electric infrastructure:
  - Predominantly charging stands and battery infrastructure (inc.battery swapping)
  - 1.8 tCO_2/car =~5% total lifecycle emissions for a gasoline vehicle (Nansai, 2001)

Infrastructure ï Cycling and Walking

- Not previously covered in our research.
- Cycling sometimes part of the road infrastructure, but also in many cases separate infrastructure, alongside walking infrastructure.
- Often concrete or asphalt surfaces – similar to road construction, but with less stringent requirements.
- Information available on design guidelines (at national level, e.g. DfT and Sustrans in UK).
- Additional infrastructure/maintenance requirements to roads, e.g.: lighting (where facilities are separated from the main highway), safety railings, crossing infrastructure, cycle parking, bus shelters/waiting areas (when combining walk/cycle and ride) etc.
- No data yet identified on GHG imp compare with other modes.

Vehicle Production and ELV - Overview

- Considered the following modes:
  - Road;
  - Rail;
  - Aviation; and
  - Shipping.

- Included emissions from (where available):
  - Production of vehicles; and
  - Disposal, dismantling and recycling of vehicles.

Vehicle Production - Road

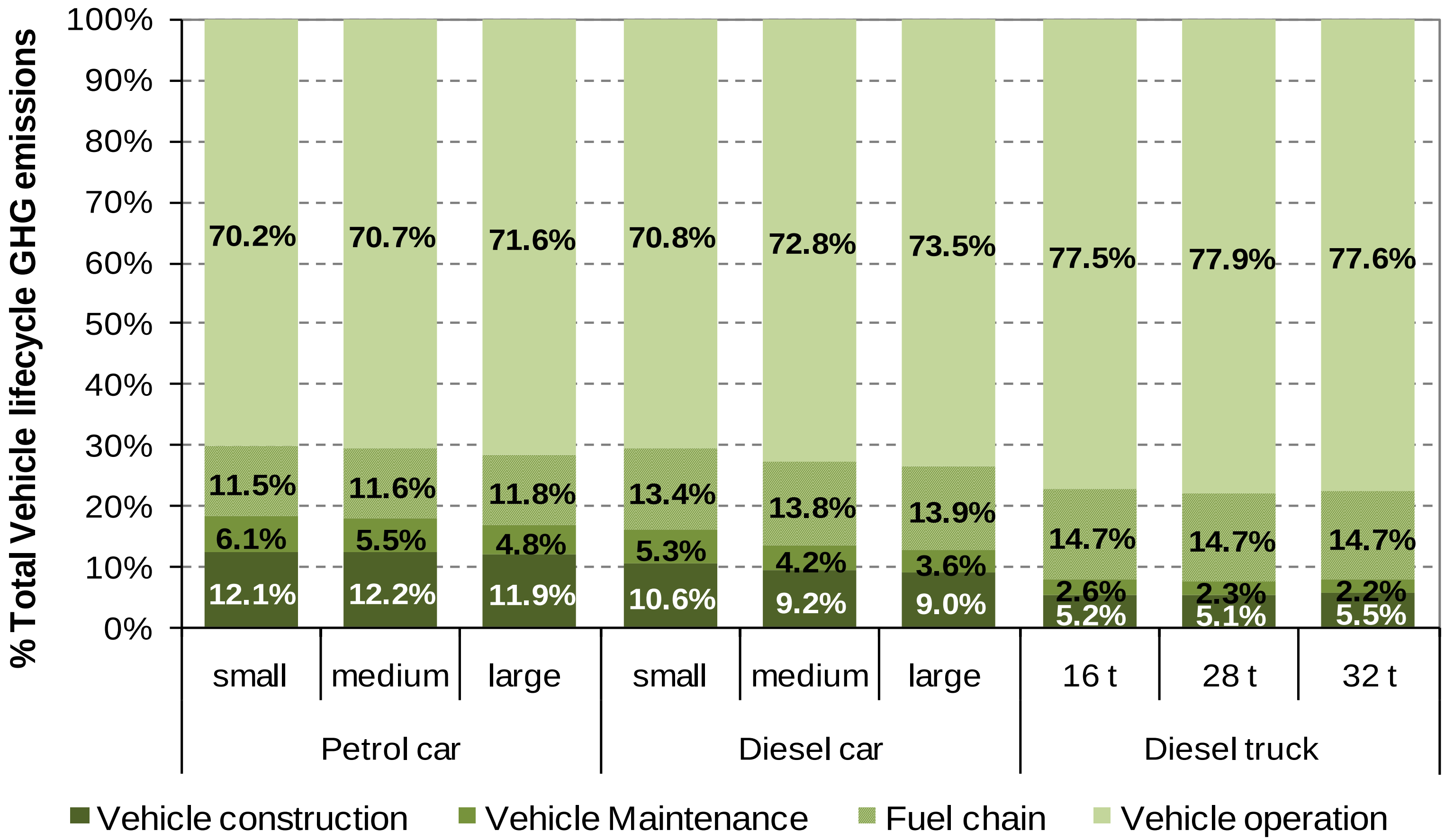
Conventional cars

- Road vehicle lifetimes generally 10-15 years (longer in S & E Europe).
- Materials ~60% total emissions for road vehicle production/manufacture.
- *Conventional ICE (i.e. petrol, diesel) cars:* production/disposal ~10-16% total, with maintenance up to ~50% of production emissions.
- *Electric and fuel cell cars:* current production emissions up to 2 x conventional.

Vehicle Production - Road

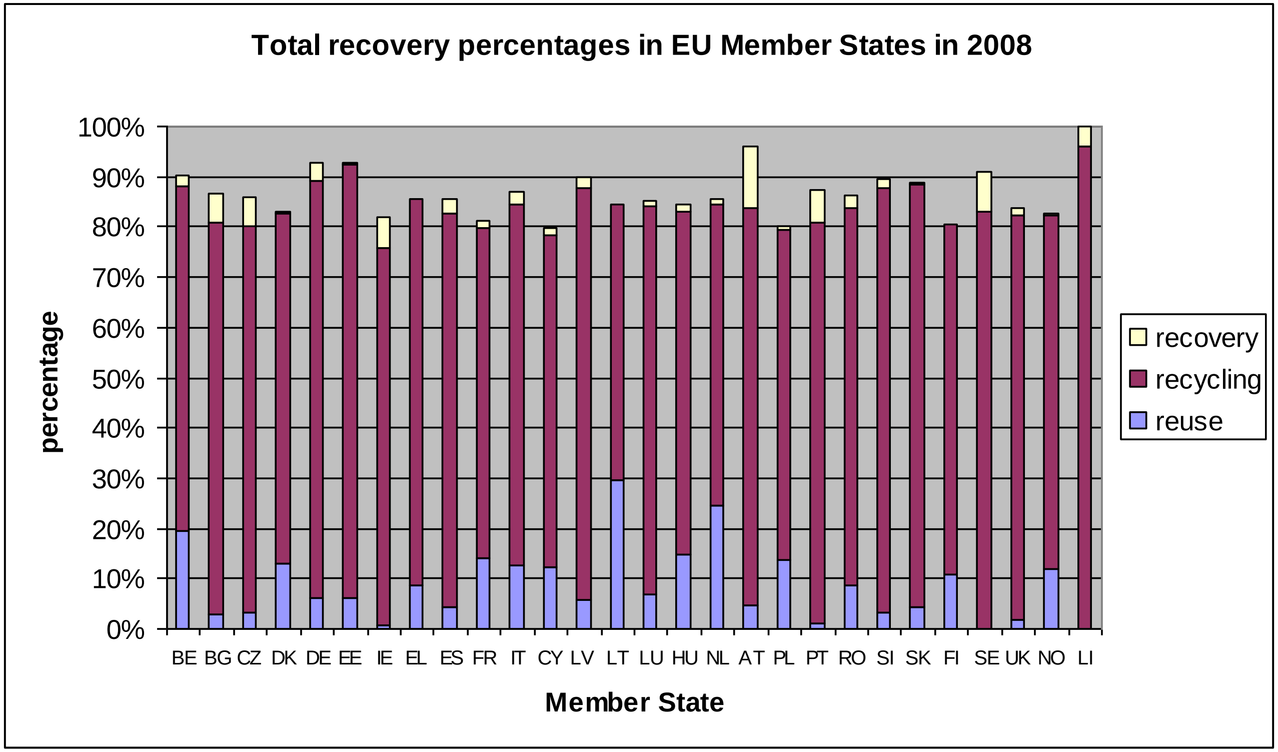
Cars and Heavy trucks

- Comparison of overall car and truck vehicle lifecycle emissions:
  - Maintenance 40-50% production emissions
  - Heavy trucks per tkm – vehicle production ~5% total lifecycle emissions



Vehicle ELV - Road

Total recovery percentages in EU Member States in 2008



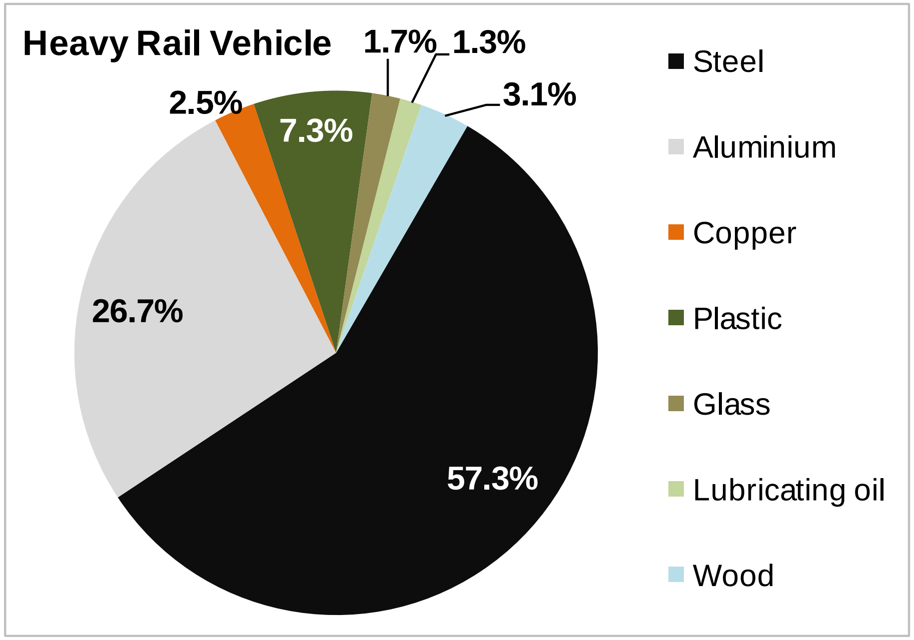
- Germany, UK, France, Spain and Italy accountable for 75% of all deregistrations of vehicles.
- Recycling has the highest rate – high proportion of steel in cars.

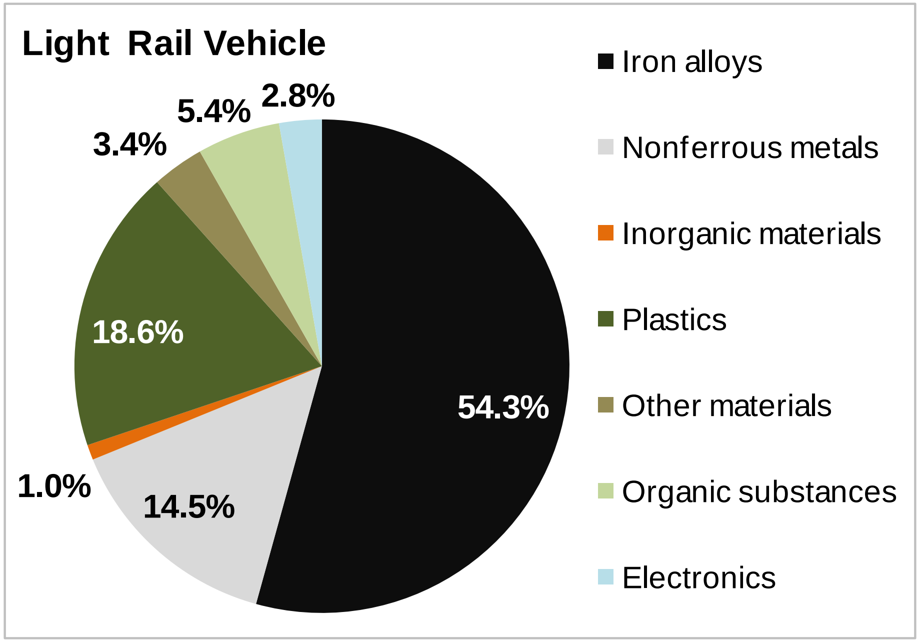
Vehicle ELV - Road

- Recycling/reusability for new vehicles in EU 85% from 2008, 95% total recovery.
- Equivalent rates for all vehicles (cars) in EU from 2015.
- End of life processing GHG emissions seem to be very small with exception of energy stored in recycled materials to be used.
- Estimated at 0.2% of total lifecycle emissions of passenger vehicles.
- However, important stage of the lifecycle process:
  - Using recycled cast and wrought aluminium instead of virgin aluminium saves 70% and 73% of GHG emissions respectively.
  - Steel recycling saves 60% GHG emissions compared to use of virgin steel.
  - Increasing steel recycling rates to 90% from 70% would reduce emissions from conventional vehicles by 11%.

Vehicle Production and ELV - Rail

- Rail rolling stock has long lifetime (30-40yrs) and high activity.
- Materials ~60% total emissions for rail vehicle production/manufacture
- GHG emissions from rolling stock construction due to use of materials is dominated by use of Steel, Aluminium and Plastics:

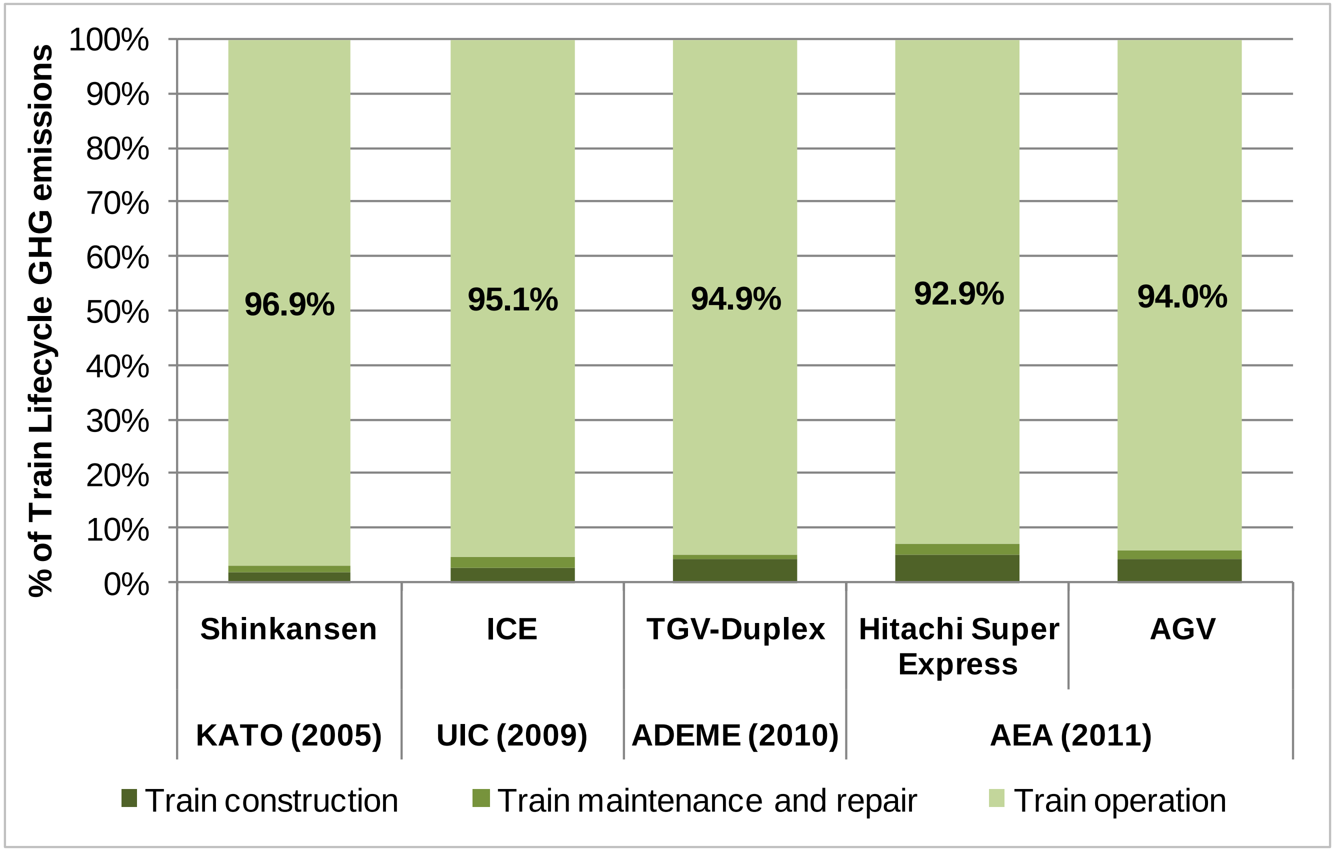




Source: Heavy vehicle estimates based on electric multiple unit material breakdown from AEA (2007).
Light rail vehicle estimates based on data from Siemens (2010)

Vehicle Production and ELV - Rail

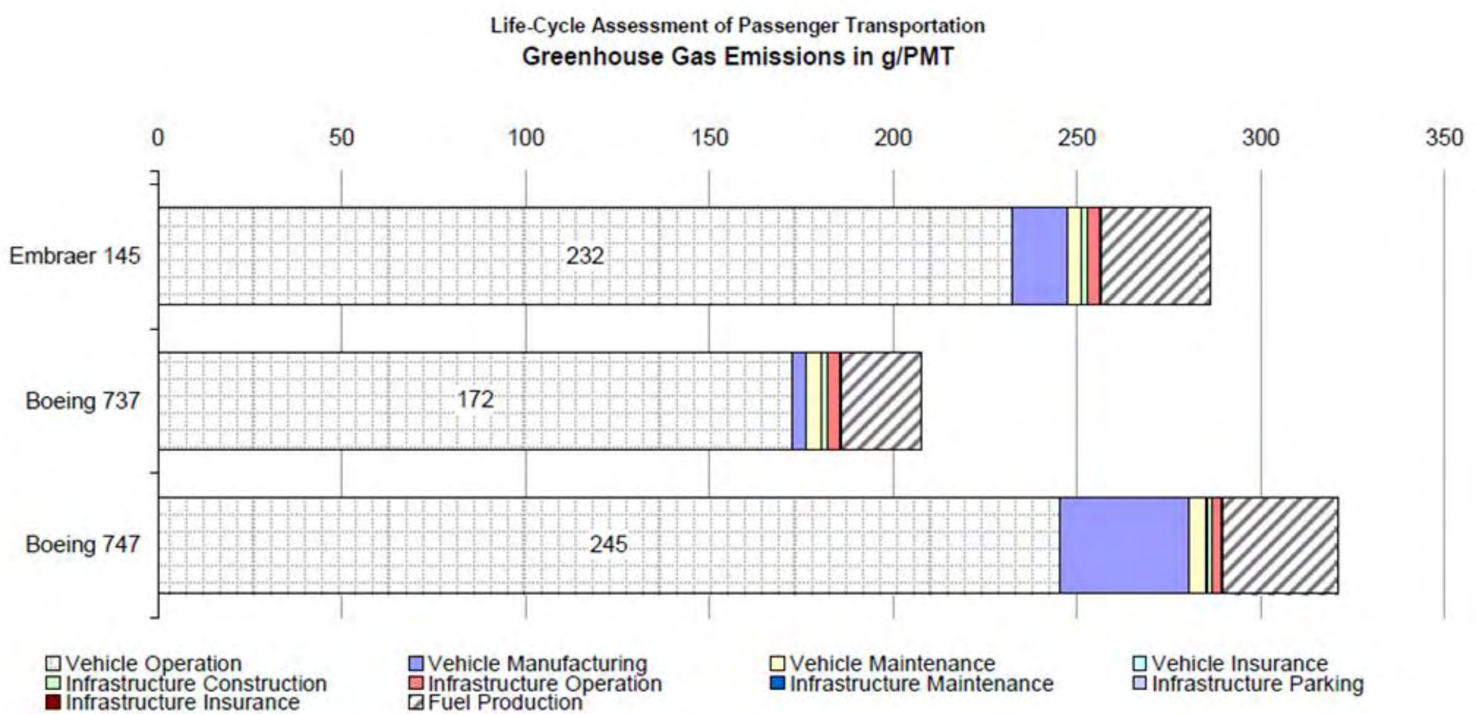
- Comparison of overall electric rolling stock lifecycle emissions:
  - Estimates based on information collected from different literature sources,
  - Train operational emissions normalised to projected 30-year average EU electricity mix between 2010 and 2040.



Vehicle Production - Aviation

- Primary GHG emissions/energy factors in manufacturing of aircraft:
  - Electricity usage at manufacturing facilities; and
  - Diesel consumed in truck transportation moving parts for assembly.
- Manufacturing emissions account for approx. 4-11% aircraft lifecycle GHG emissions.

Lifecycle assessment of aircraft (g/PMT) (Chester and Horvarth, 2007)



Vehicle ELV - Aviation

- Estimated that up to 85% of the aircraft weight can be recycled.
- More than 70% of components and materials can be reused or recovered through regulated recovery channels.
- Translates to a reduction in land-filled waste from 45% to 15%.
- Aluminium primary material used in construction of aircraft.

End of life scenario for the A330-200 aircraft (PAMELA)

Aircraft Section		Material	Disposal Scenario	Valuable (Kg)	Wasted (Kg)
Fuselage		Composites	50 % Incineration; 50 % Landfill	0	1885
		Aluminium	85% Recycle; 15% Landfill	19882	3509
		Steel	85 % Recycle; 15% Landfill	161	28
		Titanium	50 % Incineration; 50 % Landfill	625	625
		Misc.	50 % Incineration; 50 % Landfill	391	391
Wing		Composites	50 % Incineration; 50% Landfill	1679	1679
		Aluminium	70% Recycle; 30% Landfill	25750	11036
		Steel	75 % Recycle; 25% Landfill	928	309
		Titanium	50 % Recycle; 50 % Landfill	0	2341
Vertical and Horizontal Stabilizer		Composites	50 % Incineration; 50% Landfill	0	2928
		Aluminium	64 % Recycle; 36% Landfill	90	51
MLG and NG		All materials	80% Re-use; 20% Landfill	10806	2702
Engine	GE CF6-E1	All materials	75% Re-use; 25% Landfill	8100	2700
	Structure	Titanium	50 % Incineration; 50 % Landfill	0	1249
		Composites	50 % Incineration; 50 % Landfill	0	2018
		steel	80 % Recycle; 20% Landfill	3486	871
			TOTAL WEIGHT (in Kg)	**71898**	**34321**
			in percentage (%)	**68**	**32**

Source: Lopes, 2010

Vehicle Production - Ships

- CO_2 emissions from the manufacture of vessels largely from the production/processing of steel and energy consumption at ship yards.
- Estimation of the CO_2 emissions associated with ship production are approximately 2-3% of the total lifecycle of ship.
- For example, lifecycle of transoceanic tanker estimated as follows:
  - Operation of ship - 83%;
  - Port Operation – 15%;
  - Ship Production – 2%;
  - Maintenance – 0.01%; and
  - Construction of port facilities – 0.01% (Walnum, 2011)
- However, study by Simonsen (2010) estimated a range of between 2.26% to 12.46% for ship production across a wide range of ship types.

Vehicle ELV - Ships

- Little known regarding which ship dismantling routes are followed and to what extent (globally).
- Ship scrapping process likely to result in:
  - Ferrous materials: steel plates and sections, pipes stiffened panels, cast iron, cast steel etc;
  - Non-ferrous materials: copper, brass, bronze, aluminium, zinc etc;
  - Non-metallic materials;
  - Equipment: electrical, navigation, electronic, communication etc; and
  - Machinery: cranes, winches, motors, pumps etc, and engines: main and auxiliary.
- The extent to which steel is being recycled is important from a GHG perspective.
- Assuming steel recycling rate of 95%, disposal of a vessel leads to a CO_2 ‘credit’ of approximately 2% of
- Production and disposal processes emissions is expected to be in the order of 1%.

Next steps ï Reaching optimal solutions

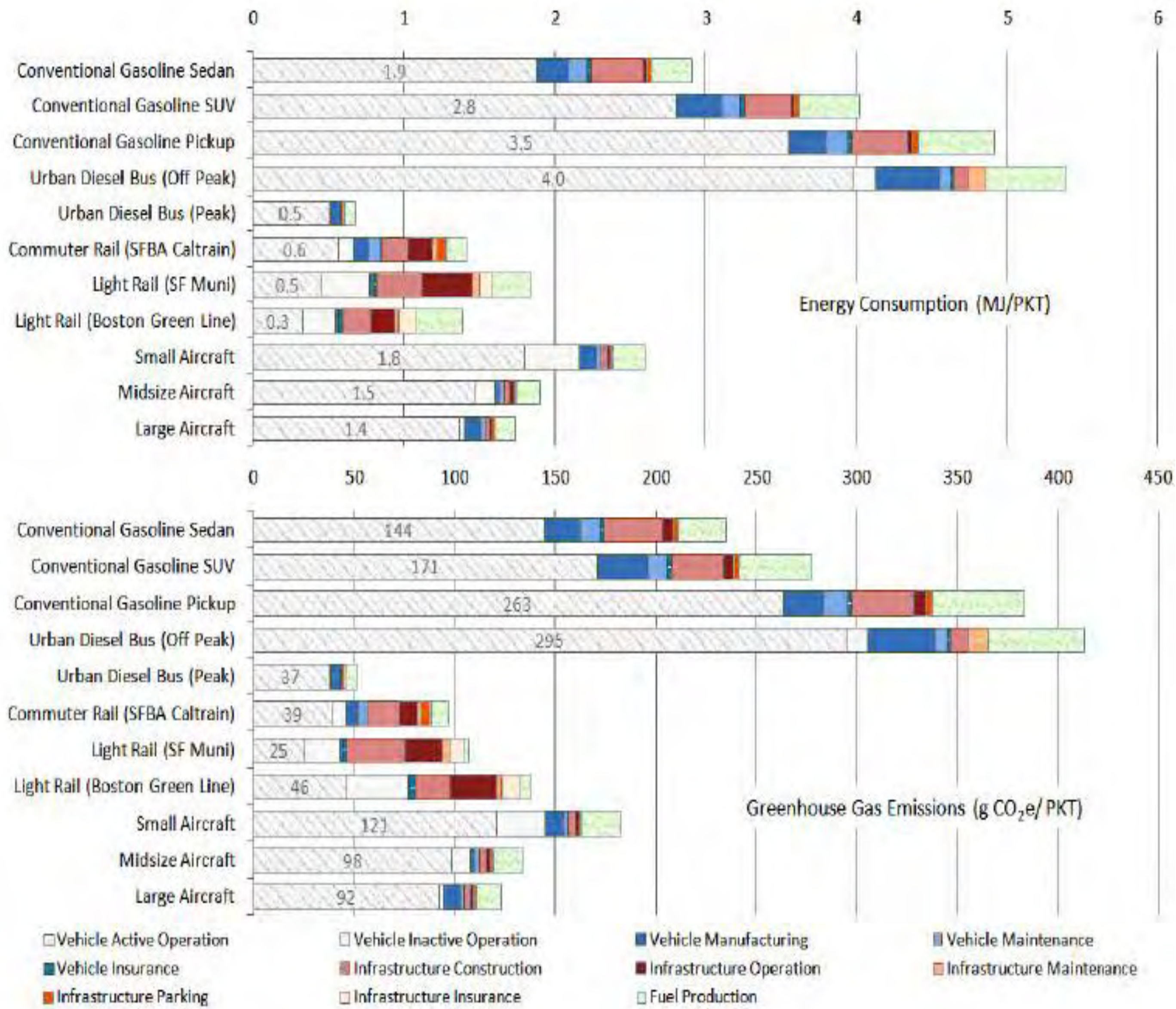
To provide:

- A summary comparison of current and (possible) future relative significance of emission components versus vehicle in-use emissions by mode of transport.
- An assessment of the possible impacts of including emissions from infrastructure and vehicle production and disposal in the relative performance of different scenario options for reducing GHG emissions in the long term to 2050.
  - Attempt to bring together the modal comparisons as far as possible.
  - However, will need to consider the problems with assumptions (e.g. roads in particular).

Next steps ï Reaching optimal solutions

Lifecycle assessment of passenger transport per passenger km travelled (PKT) (Chester and Horvarth, 2009) -

Demonstrates the relative importance of components for road, rail and air



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Next steps ï Reaching optimal solutions

- High-level consideration of footprint of transport infrastructure potential scale of land use change impacts (current vs future):
  - Land Use Transport Interaction (LUTI) modelling currently subject of much discussion.
  - Existing research will be reviewed.
  - Data available types of land displaced in Europe and percentage increase in land take per year for road and rail infrastructure – possible estimation of emissions based on standard emission factors for replacing various types of land.
  - Building of transport infrastructure not only affects the land it uses, but also the surrounding area if a new transport link attracts commerce, industry or housing. Two studies look into this, but no estimates of any CO_2 consequences are calculated.