Transport and Climate Change – Main Messages from AR5
Feb 2015, Istanbul
Total Annual GHG Emissions by Groups of Gases 1970-2010
• GHG emissions growth - 49 GtCO$_{2eq}$/year in 2010 (highest in history)
• CO2 main GHG;
• 80% of emission increase is due to fossil fuel.
Allocation of GHG emission across economic sectors in 2010

**Share of direct emissions**

- AFOLU: 24%
- Energy: 10.75%
- Industry: 10.75%
- Transport: 7.21%
- Buildings: Commercial: 5.12%
- Buildings: Residential: 3.94%
- Road: 2.92%
- Waste: 0.30%
- Other: 0%

**Share of direct and indirect emissions**

- AFOLU: 23.96%
- Industrial Buildings: 17.69%
- Commercial: 10.17%
- Residential: 2.92%
- Flaring and Fugitive: 0.88%
- Other: 0.30%
- Other: 0.27%

Electricity and Heat: 1.08%
Transport Sector produced 7.0 Gt CO\textsubscript{2}-eq of direct emissions in 2010 (responsible for approximately 23% of total energy-related CO2 emissions).

Transport emissions could increase at a faster rate than emissions from any other energy end use sector and reach around 12 Gt CO\textsubscript{2}-eq by 2050.
• **Activity** – Total passenger-km/yr or freight tonne-km/yr having a positive feedback loop to the state of the economy but, in part, influenced by behavioural issues such as journey avoidance and restructuring freight logistics systems;

• **system infrastructure and modal choice**;

• **energy intensity** – directly related to vehicle and engine design efficiency, driver behaviour during operation, and usage patterns;

• **fuel carbon intensity** - varies for different transport fuels including electricity and hydrogen.
GHG EMISSION DECOMPOSITION

System-Infrastructure Modal Choice
- p-km$_{mode}$/p-km$_{total}$
- t-km$_{mode}$/t-km$_{total}$

Fuel Carbon Intensity
- t CO$_2$eq / MJ

... of:
- Diesel
- Gasoline
- CNG / LPG
- Biofuels
- Electricity
- Hydrogen

Energy Intensity
- MJ / p-km
- MJ / t-km

... of:
- Light Duty Vehicles (LDVs), 2-3-Wheelers
- Heavy Duty Vehicles (HDVs), Buses
- Trains
- Aircraft
- Ships and Boats
- Cycling, Walking
- Occupancy / Loading Rate

Activity
- p-km$_{total}$
- t-km$_{total}$

- Number of Journeys
- Journey Distance
- Journey Avoidance (Combining Trips, Video Conferencing, etc.)

Total GHG Emissions = \[ \sum_{\text{Modal Shares}} + \sum_{\text{Fuels}} \left( \text{Fuel Carbon Intensity} \times \text{Energy Intensity} \times \text{Activity} \right) \]

Notes: p Km = Passenger-Km; t Km = tonne-Km;
CNG = compressed natural gas; LPG = liquid petroleum gas.
Transport’s share of total national GHG emissions range from up to 30% in high income economies to less than 3% in LDCs, mirroring the status of their industry and service sectors.

Drivers:
- Travel time budged;
- Personal income increase;
- Costs and prices;
- Social and cultural factors.

Petroleum product consumption to meet all transport (2009)

North America: 100 Gj/capita each year

India and China: 2 Gj/capita each year

Newman and Kenworthy, 2001
GHG emissions:
• Non-OECD countries will contribute with 2/3 of total LDV ownership, that it is expected to double in the next few decades. Reaching 1 billion vehicles;
• OECD countries will keep increasing air transport demand.

Recent trends suggest that economic, lifestyle, and cultural changes will be insufficient to mitigate global increases in transport emissions without stringent policy instruments, incentives, or other interventions being needed.
Technology Improvement and New Technology-related practice can make substantial contributions to climate change mitigation in transport sector

- Design of new engines and vehicles (fuel economy)
- New Fuels and Alternative energy sources
- Telecomunication facilities
NON TECH OPTIONS TO REDUCE GHG IN TRANSPORT

- **Avoiding journey** where possible – by, for example, densifying urban landscapes, sourcing localized products, internet shopping, restructuring freight systems, and utilizing advanced information and communication technologies (ICT);

- **Modal shift** to lower-carbon transport systems, - encouraged by increasing investment in public transport, walking and cycling infrastructure, and modifying roads, airports, ports and railways to become more attractive for users and minimize travel time and distance;

- **Lowering energy intensity** (MJ/ passenger Km or MJ/tonne Km) – by enhancing vehicle and engine performance, using lightweight materials, increasing freight load factors and passenger occupancy rates, deploying new technologies such as electric three-wheelers;

- **Reducing carbon intensity of fuels** (CO$_2$-eq/MJ) – by substituting oil-based products with natural gas, bio-methane, or biofuels, electricity or hydrogen produced from low GHG sources.

In addition, indirect GHG emissions arise during the construction of infrastructure, manufacture of vehicles, and provision of fuels (well-to-tank).
Developments to improve infrastructure in rapidly urbanizing developing countries will decisively determine the future energy intensity of transport and concomitant emission, requiring policies and actions to avoid lock-in.

Existing vehicle stock, road infrastructure and fuel-supply infrastructure prescribe future use and can lock-in emission paths for decades while inducing similar investment because of economies of scale. The life span of these infrastructure ranges from 50 to more than 100 years.

Opportunities exist to substantially reduce these infrastructure related emissions, for instance by up to 40% in rail by the increased deployment of low-carbon materials and recycling of rail track materials at their end –of-life.

GHG emissions per passenger-quilometre (p-Km) or per tonne-quilometre (t-Km) depend, *inter alia*, on the intensity of use of infrastructure and the share of tunnels, bridges, runways etc.
Transport demand and land use are closely inter-linked.

Urban population density inversely correlates with GHG emissions from land transport and enables non-motorised to be more viable. However, there exists a non-linear relationship between urban density and modal choice.
Socio-economic, environmental and health effects
• Energy security;
• Access and mobility;
• Employment impact;
• Traffic congestion;
• Health;
• Safety; and,
• Fossil fuel displacement.
Co-benefits *(green arrows)* and adverse side-effects *(orange arrows)* of the main mitigation measures in the transport sector.

<table>
<thead>
<tr>
<th>Mitigation measures</th>
<th>Effect on additional objectives/concerns</th>
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<tbody>
<tr>
<td></td>
<td>Economic</td>
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<tr>
<td>Reduction of fuel carbon intensity: electricity, hydrogen, CNG, biofuels and other fuels.</td>
<td>↑ Energy security (reduced oil dependence and exposure to oil price volatility) (1,2,3,32,33,34,94)</td>
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<td>↑ Technological spillovers (e.g. battery technologies for consumer electronics) (17,18,44,55,90)</td>
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<td>↓ Road safety (silent electric LDVs at low speed) (56)</td>
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<td>Reduction of energy intensity.</td>
<td>↑ Energy security (reduced oil dependence and exposure to oil price volatility) (1,2,3,32,33,34)</td>
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<td>Compact urban form and improved transport infrastructure. Modal shift.</td>
<td>↑ Energy security (reduced oil dependence and exposure to oil price volatility) (77-80,86)</td>
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<td>↑ Productivity (reduced urban congestion and travel times, affordable and accessible transport) (6,7,8,26,35,45,46,48,49)</td>
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<td>↑ Employment opportunities in the public transport sector vs car manufacturing jobs (38,76,89)</td>
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<td>Journey distance reduction and avoidance.</td>
<td>↑ Energy security (reduced oil dependence and exposure to oil price volatility) (31,77-80,86)</td>
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<td></td>
<td>↑ Productivity (reduced urban congestion, travel times, walking) (6,7,8,26,45,46,49)</td>
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Transport Tech & Practices with potential for both short- and long-term GHG reduction and the related barriers & opportunities

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<tr>
<th>Transport technology or practice</th>
<th>Short-term possibilities</th>
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<th>Barriers</th>
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<tr>
<td>1. BEVs and PHEVs based on renewable electricity.</td>
<td>Rapid increase in use likely over next decade from a small base, so only a small impact likely in short-term.</td>
<td>Significant replacement of ICE-powered LDVs.</td>
<td>EV and battery costs reducing but still high. Lack of infrastructure, and recharging standards not uniform. Vehicle range anxiety. Lack of capital and electricity in some least developed countries.</td>
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<td>2. CNG, LNG, CBG and LBG displacing gasoline in LDVs and diesel in HDVs.</td>
<td>Infrastructure available in some cities so can allow a quick ramp-up of gas vehicles in these cities.</td>
<td>Significant replacement of HDV diesel use depends on ease of engine conversion, fuel prices and extent of infrastructure.</td>
<td>Insufficient government programmes, conversion subsidies and local gas infrastructure and markets. Leakage of gas.</td>
<td>Demonstration gas conversion programmes; that show cost and health co-benefits. Fixing gas leakage in general.</td>
<td>IEA 2007; Salter et al. 2011; Alvarez et al. 2012</td>
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<tr>
<td>3. Biofuels displacing gasoline, diesel and aviation fuel.</td>
<td>Niche markets continue for first generation biofuels (3% of liquid fuel market, small biogas niche markets).</td>
<td>Advanced and drop-in biofuels likely to be adopted around 2020-2030, mainly for aviation.</td>
<td>Some biofuels can be relatively expensive, environmentally poor and cause inequalities by inducing increases in food prices.</td>
<td>Drop-in fuels attractive for all vehicles. Biofuels and bio-electricity can be produced together, e.g. sugarcane ethanol and CHP from bagasse. New biofuel options need to be further tested, particularly for aviation applications.</td>
<td>Ogden et al. 2004; Farglone et al. 2010; IEA 2010; Plevin et al., 2010; Creutzig, et al. 2011; Salter et al., 2011; Paccia and Moreira, 2011; Flannery et al., 2012</td>
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<td><strong>Energy intensity: efficiency of technologies</strong> FEV – fuel efficient vehicles ICE – Internal combustion engine</td>
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<td><strong>4. Improved vehicle ICE technologies and on-board information and communication technologies (ICT) in fuel efficient vehicles.</strong></td>
<td>Continuing fuel efficiency improvements across new vehicles of all types can show large, low-cost, near-term reductions in fuel demand.</td>
<td>Likely to be a significant source of reduction. Behavioural issues (e.g. rebound effect). Consumer choices can reduce vehicle efficiency gains.</td>
<td>Insufficient regulatory support for vehicle emissions standards. On-road performance deteriorates compared with laboratory tests.</td>
<td>Creative regulations that enable quick changes to occur without excessive costs on emissions standards. China and most OECD countries have implemented standards. Reduced registration tax can be implemented for low CO₂e-based vehicles.</td>
<td>Schipper et al., 2000; Ogden et al., 2004; Small and van Dender, 2007; Sperling and Gordon, 2009; Timilsina and Dalal, 2009; Fuglevedt et al., 2009; Mikler, 2010; Salter et al., 2011</td>
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<td><strong>Structure: system infrastructure efficiency</strong></td>
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<td><strong>5. Modal shift by public transport displacing private motor vehicle use.</strong></td>
<td>Rapid short-term growth already happening.</td>
<td>Significant displacement only where quality system infrastructure and services are provided.</td>
<td>Availability of rail, bus, ferry and other quality transit options. Density of people to allow more access to services. Levels of services. Time barriers on roads without right of way Public perceptions.</td>
<td>Investment in quality transit infrastructure, density of adjacent land use and high level of services using innovative financing that builds in these features. Multiple co-benefits especially where walkability health benefits are a focus.</td>
<td>Kenworthy, 2008; Millard-Ball &amp; Schipper, 2011; Newman and Kenworthy 2011; Salter et al., 2011; Buehler and Pucher, 2011; Newman and Matan, 2013</td>
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<td><strong>6. Modal shift by cycling displacing private motor vehicle use.</strong></td>
<td>Rapid short term growth already happening in many cities.</td>
<td>Significant displacement only where quality system infrastructure is provided.</td>
<td>Cultural barriers and lack of safe cycling infrastructure and regulations. Harsh climate.</td>
<td>Demonstrations of quality cycling infrastructure including cultural programmes and bike-sharing schemes.</td>
<td>Bassett et al., 2008; Garrard et al., 2008; Salter et al., 2011; Anon, 2012; Sugiyama et al., 2012</td>
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<td><strong>7. Modal shift by walking displacing private motor vehicle use.</strong></td>
<td>Some growth but depends on urban planning and design policies being implemented.</td>
<td>Significant displacement where large-scale adoption of polycentric city policies and walkable urban designs are implemented.</td>
<td>Planning and design policies can work against walkability of a city by too easily allowing cars into walking city areas. Lack of density and integration with transit. Culture of walkability.</td>
<td>Large scale adoption of polycentric city policies and walkable urban designs creating walking city in historic centres and new ones. Cultural programmes.</td>
<td>Gehl, 2011; Höjer et al., 2011; Leather et al., 2011; Salter et al., 2011</td>
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<td>8.</td>
<td>Urban planning by reducing the distances to travel within urban areas.</td>
<td>Immediate impacts where dense transit-oriented development (TOD) centres are built.</td>
<td>Significant reductions where widespread polycentric city policies are implemented.</td>
<td>Urban development does not always favour dense TOD centres being built. TODs need quality transit at their base. Integration of professional areas required.</td>
<td>Widespread polycentric city policies implemented with green TODs, backed by quality transit. Multiple co-benefits in sprawl costs avoided and health gains.</td>
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<td>9.</td>
<td>Urban planning by reducing private motor vehicle use through parking and traffic restraint.</td>
<td>Immediate impacts on traffic density observed.</td>
<td>Significant reductions only where quality transport alternatives are available.</td>
<td>Political barriers due to perceived public opposition to increased costs, traffic and parking restrictions. Parking codes too prescriptive for areas suited to walking and transit.</td>
<td>Demonstrations of better transport outcomes from combinations of traffic restraint, parking and new transit/walking infrastructure investment.</td>
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<td>11.</td>
<td>Modal shift of freight by displacing HDV demand with rail.</td>
<td>Suitable immediately for medium- and long-distance freight and port traffic.</td>
<td>Substantial displacement only if large rail infrastructure improvements made, the external costs of freight transport are fully internalised and the quality of rail services are enhanced. EU target to have 30% of freight tonne-km moving more than 300km to go by rail (or water) by 2030.</td>
<td>Inadequacies in rail infrastructure and service quality. Much freight moved over distances that are too short for rail to be competitive.</td>
<td>Upgrading of inter-modal facilities. Electrification of rail freight services. Worsening traffic congestion on road networks and higher fuel cost will favour rail.</td>
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<td>12.</td>
<td>Modal shift by displacing truck and car use through waterborne transport.</td>
<td>Niche options already available. EU “Motorways of the Sea” programme demonstrates potential to expand short-sea shipping share of freight market.</td>
<td>Potential to develop beyond current niches, though will require significant investment in new vessels and port facilities.</td>
<td>Lack of vision for water transport options and land-locked population centres. Long transit times. Tightening controls on dirty bunker fuel and SOx and NOx emissions raising cost and reducing modal competitiveness.</td>
<td>Demonstrations of quality waterborne transport that can be faster and with lower-carbon emissions than alternatives.</td>
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<td>13. System optimization by improved road systems, freight logistics and efficiency at airports and ports.</td>
<td>Continuing improvements showing immediate impacts.</td>
<td>Insufficient in long term to significantly reduce carbon emissions without changing mode, reducing mobility, or reducing fuel carbon intensity.</td>
<td>Insufficient regulatory support and key performance indicators (KPIs) covering logistics and efficiency.</td>
<td>Creative regulations and KPIs that enable change to occur rapidly without excessive costs.</td>
<td>Pels and Verhoef, 2004; A. Zhang and Y. Zhang, 2006; Fuglestad et al., 2009; Kaluza et al., 2010; McKinnon, 2010; Simaiakis and Balakrishnan, 2010; Salter et al., 2011</td>
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<td>Activity: demand reduction</td>
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<td>14. Mobility service substitution by reducing the need to travel through enhanced communications.</td>
<td>Niche markets growing and ICT improving in quality and reliability.</td>
<td>Significant reductions possible after faster broadband and quality images available, though ICT may increase the need for some trips.</td>
<td>Technological barriers due to insufficient broadband in some regions.</td>
<td>Demonstrations of improved video-conferencing system quality.</td>
<td>Golob and Regan, 2001; Choo et al., 2005; Wang and Law, 2007; Yi and Thomas, 2007; Zhen et al., 2009; Salter et al., 2011; Mokhtarian and Meenakshisundaram, 2002</td>
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<td>15. Behavioural change from reducing private motor vehicle use through pricing policies, eg network charges and parking fees.</td>
<td>Immediate impacts on traffic density observed.</td>
<td>Significant reductions only where quality transport alternatives are available.</td>
<td>Political barriers due to perceived public opposition to increased pricing costs. Lack of administrative integration between transport, land-use and environment departments in city municipalities.</td>
<td>Demonstrations of better transport outcomes from combinations of pricing, traffic restraint, parking and new infrastructure investment from the revenue. Removing subsidies to fossil fuels important for many co-benefits.</td>
<td>Uttman, 2005, 2006; Salter et al., 2011; Creutzig et al., 2012</td>
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<tr>
<td>16. Behavioural change resulting from education to encourage gaining benefits of less motor vehicle use.</td>
<td>Immediate impacts of 10-15% reduction of LDV use are possible.</td>
<td>Significant reductions only where quality transport alternatives are available.</td>
<td>Lack of belief by politicians and professionals in the value of educational behaviour change programmes.</td>
<td>Demonstrations of ‘travel smart’ programmes linked to improvements in sustainable transport infrastructure. Cost effective and multiple co-benefits.</td>
<td>Pandey, 2006; Goodwin and Lyons, 2010; Taylor and Philp, 2010; Ashton-Graham et al., 2011; Höjer et al., 2011; Salter et al., 2011</td>
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Possible pathways towards stabilization

• Economic tools/co-benefits inclusion;
• Innovation and deployment of low carbon tech;
• Behavior change;
• Role of Subsides.
Final Remarks

• Without explicit efforts to reduce GHG emissions, the fundamental drivers of emissions growth are expected to persist.

• Infrastructure development that lock societies into GHG-intensive emissions pathways may be difficult or very costly to change.

• Behavior, lifestyle, and culture have a considerable influence on energy use and its emission.