Major Economies and Climate Change Research Group

The High Cost of Mobility: Reducing GHG Emissions from Transport

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ACRONYMS AND ABBREVIATIONS

2DS	2 Degree Scenario
4DS	4 Degree Scenario
ADB	Asian Development Bank
ASEAN	Association of South East Asian Nations
ASI	Avoid - Shift - Improve framework
BAU	Business as Usual
BRT	Bus Rapid Transit
CAFE	Corporate Average Fuel Economy
CAIT	Climate Analysis Indicators Tool
CCAP	Center for Clean Air Policy
CDM	Clean Development Mechanism
CERs	Certifiable Emissions Reductions
CNGs	Compressed Natural Gas
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
ETP	Energy Technology Perspective
EU	European Union
EVs	Electric Vehicles
GHG	Greenhouse Gas
GtCO2e	Giga tonnes of CO_2 equivalent
HDVs	Heavy duty vehicles
ICAO	International Civil Aviation Organization
ICCT	International Council for Clean Transportation
IEA	International Energy Agency
IMF	International Monetary Fund
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
KP	Kyoto Protocol
LDVs	Light duty vehicles
LEDS	Low emissions development strategy
MDV	Medium Duty Vehicle
MRV	Monitoring, Results, and Verification
MtCO2e	Metric tonnes of CO_2 equivalent
Mtoe	Million tonnes of oil equivalent
NHTSA	National Highway Traffic Safety Administration
OECD	Organization for Economic Cooperation and Development
Pkm	Passenger kilometers
PPV	Personal passenger vehicle
SLoCaT	Sustainable low carbon transport
TDM	Transport Demand Management
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute

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EXECUTIVE SUMMARY

(1) Four largest transportation carbon emitters

The US, EU, and China are the largest overall emitters. All three rank as the top emitters in the transport sector. India is projected to join this group by 2030.

(2) Three Main Transport Emissions Reduction Strategies

- *Avoiding* transportation when possible through reducing demand for trips and emissions from transport infrastructure construction and maintenance
- *Shifting* demand away from carbon intensive transport
- *Improving* transportation through increasing fuel efficiency and alternative fuel use

(3) Potential for Emissions Reduction

- Avoid & Shift Strategies – 1 $GtCO_2e$ by 2030, 2 $GtCO_2e$ by 2050
- Improve Strategies Reducing Road Emissions– 2.5 $GtCO_2e$ s by 2030, 7 $GtCO_2e$ by 2050

Year (2009 baseline)	Total Transport Emissions Reduction Possible (ETP 2012)	Road Emissions Reduction Potential (ETP 2012)	Inferred Avoid and Shift Strategy Reductions
2030	3.5	2.5	1
2050	9	7	2

All units are expressed in $GtCO_2e$.

(4) Barriers to Implementation (by strategy)

Avoid

- User fees can disproportionately hurt low income groups
- Large disparities in the amount of funds available for infrastructure improvements
- Three out of the four countries/regions in this study (all except China) are highly decentralized in their decision making

Shift

- Lack of investment (US), market saturation (EU)
- Shift is only highly effective in high density population areas
- Prevalence and increase of car culture
- Authoritarian states can shape behavior more effectively than democracies

Improve

- Lack of legislative will for top-down emissions regulations
- General uncertainty about monetary savings from end users
- Ambiguous delineation of responsibility for air and sea emissions
- Alternative fuels require extensive infrastructure investment

(5) Policy Recommendations

General

- Encourage alternative fuel use by increasing taxes on fossil fuels and subsidizing electric vehicle charging infrastructure.
- Reduce carbon intensity of transport through shifting demand for passenger travel and freight from road to rail.
- Continue to pursue fuel efficiency standards and promote emissions regulations in developing countries.
- Expose the true cost of carbon-intensive mobility through internalizing the cost of environmental damage and phasing out fossil fuel subsidies.
- Frame low carbon transport as providing co-benefits such as improved air quality, reduced congestion, and the increased cost effectiveness of travel.
- Increase access to information and support for carbon mitigating development projects.

United States

- **Avoid** - Develop LEED-type standards for transportation infrastructure.
- **Shift** - Create plan for national transport hub system that heavily incorporates multi-modal travel, including light rail.
- **Improve** - Continue to implement progressive fuel economy standards for LDVs and set aggressive standards for MDVs and HDVs.

European Union

- **Avoid** - Conduct case studies on cap and trade policies' effect on member nations, model effects if implemented internationally.
- **Shift** - Market successful case studies to still developing economies like China and India looking to emulate the European Union in terms of urban planning.
- **Improve** - Expand electric vehicle charging infrastructure.

China

- **Avoid** - Determine more sustainable and equitable ways to limit demand for LDV travel, such as distance fees.
- **Shift** - Continue to explore using fiscal incentives like tax breaks to promote the use of EV and alternative fuel technology and plug-in infrastructure.
- **Improve** - Encourage partnerships between domestic and international vehicle manufacturers, to accelerate diffusion of clean technology.

India

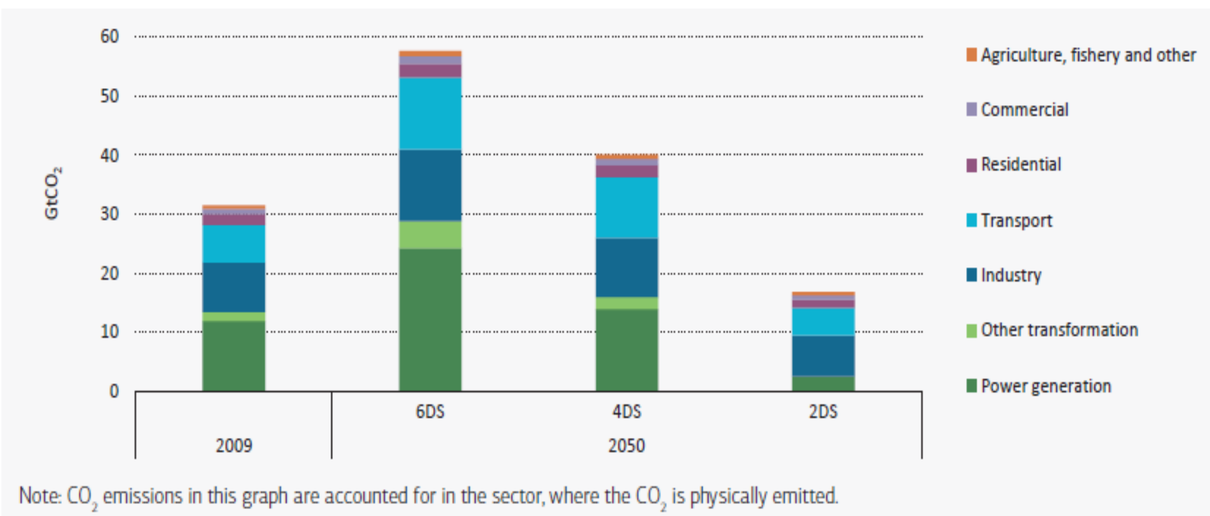
- **Avoid** - Build on existing tendencies to avoid road transport through smart growth and less carbon intensive transport infrastructure development projects.
- **Shift** - Continue to pursue rail as the dominant form of freight, and use the strength of the Black Carbon Initiative and black carbon tax to prevent lorry traffic from absorbing rail's market share of freight.
- **Improve** - Explore use of alternative fuels that can be easily integrated into transport systems

INTRODUCTION

This report reexamines historic and current strategies for reducing emissions in the transport sector in light of rapidly shifting dynamics between OECD and non-member countries. Strategies for reducing emissions are analyzed under the Avoid-Shift-Improve (ASI) framework. The first section provides an overview of the current state of emissions and fuel use in the transport sector, and then follows with future projections for growth. The three following sections will present an overview of the strategies under the ASI framework, which offer the greatest emission-reduction potential at the lowest cost. Avoid strategies under the ASI framework entail *avoiding* transportation when possible through reducing trips and reducing emissions from the construction and maintenance of transport infrastructure. Shift strategies focus on *shifting* demand away from carbon intensive transport. Improve strategies involve *improving* available methods of transportation through increasing fuel efficiency and alternative fuel use. The final section will review recommendations for decision-makers in the transport space.

CURRENT STATE OF THE TRANSPORT SECTOR

Figure 1. Global Emissions by Sector and Scenario



Source: OECD/IEA ETP 2012

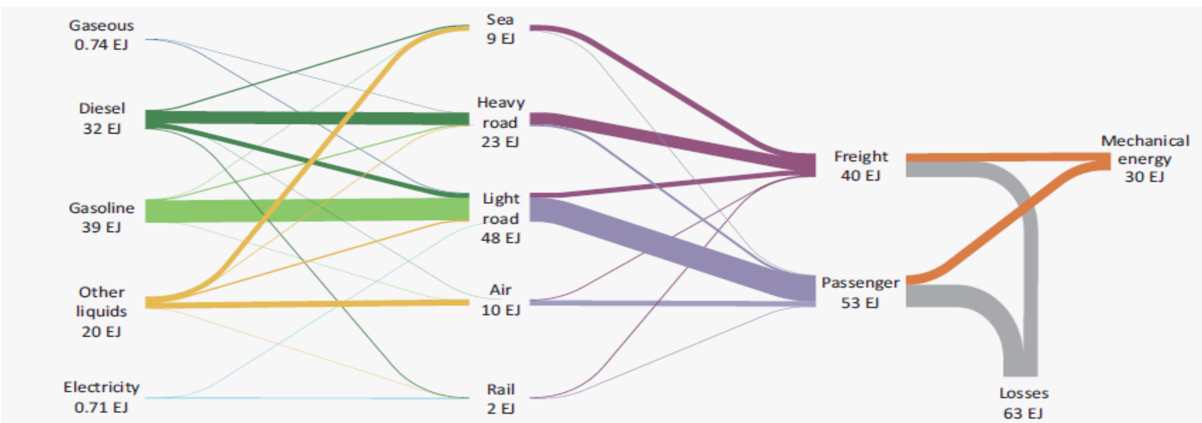
In a space responsible for many of the gains made in human economic and social growth over the past century, historic and current CO_2 emission totals related to global transport amounted to approximately 5.5 $GtCO_2e$ in 2009, or 13% of total GHG emissions excluding LULUCF[1]. For a comparative look at emission outputs in 2009 and as projected by scenario for 2050, refer to Figure 1 above. Due to an increasing global population and rapid industrialization

[1] WRI/CAIT, 2009.

of emerging economies like China and India, transport is also one of the fastest-growing sources of emissions among end-use subsectors. In fact, transport emissions as a share of the global total increased 2% from 2009 to 2010[2].

The mobility required to sustain global supply chains requires a substantial amount of fuel, and this contributes to the transport sector's heavy energy use, which composes nearly 20% of global primary use[3]. As recently as 2012, fuel use from the transport sector drew heavily from fossil fuel and inefficient fuel combustion technology. Fortunately, natural gas, biofuels, hydrogen, electricity, and refined oil products have increased in market share.[4] Figure 2 below displays this inefficiency and shows that more than two thirds of the energy put into transport systems is wasted as heat loss. Two factors render this degree of energy loss significant; first, oil accounts for 93% of the energy consumed in the transport sector, and second, it is projected that oil will continue to be the primary mover of transportation in the near and mid-term.[5]

Figure 2. Final Energy Distribution in the Transport Sector, 2009



Source: OECD/IEA ETP 2012

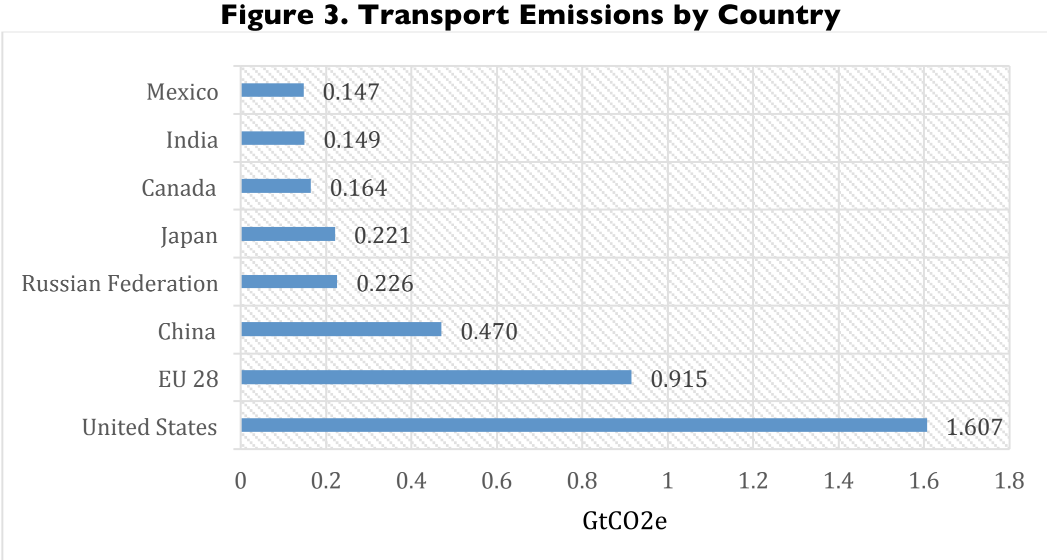
Under the avoid-shift-improve framework (ASI), the IEA indicates that improving fuel efficiency must be supplemented with mid and long-term efforts to avoid demand for travel and shift demand for carbon intensive modes of transport to low-carbon options.[6] Emerging vehicle technologies will improve fuel efficiency and allow for greater competition from vehicles running on alternative fuels, but the sector "is decarbonizing too slowly to reach the ambitious target of 2DS without targeting the source of inefficient transportation planning, or inefficient urban development and freight management".[7]

[2] ITF, 2010.
[3] OECD/IEA, 2012.
[4] Ibid. p. 170.
[5] OECD/IEA, 2012 as cited in OECD/IEA 2011a, p. 424.
[6] Ibid.
[7] The 2 Degree Celsius Scenario was first mentioned in the Copenhagen Accord in 2009, and was developed by the IEA into a large-scale, multi-sectoral strategy for reducing emissions globally so as to limit total temperature increase to 2 degrees Celsius or less. For more information, please refer to the IEA's Energy Technology Perspectives, 2012, p. 8).

Reforming the cultural, political, and economic structures responsible for poor planning will be difficult, but the end-goal should rest in bringing actors in the transport space together to pursue all low-carbon technologies without bias and balancing near and long-term priorities to effect lasting change, which will be necessary to sustain progress past the 2DS goal outlined by the Copenhagen Accord.[8] Challenges to incentivizing change in international climate change policy within the transport sector arise from the imbalance between OECD and non-member countries in terms of historical emissions output. OECD countries released 49.5% of global GHG emissions in 2005, and transport sector emissions comprised 30% of their total emissions output.[9] In order to avoid re-tracing the trajectory of countries like the United States and rely on dirty fuel and unregulated urban planning to power mobility, emerging economies like China and India must invest more carefully in the short term. The challenge for the future will rest in making low-carbon development strategies salient in terms of the long-term fiscal and quality-of-life related returns that they provide.

Current top emitters in the transport sector, however, increasingly represent a mixed list of OECD and non-member nations due to the fast-paced growth of the Chinese economy.[10] According to the World Resources Institute's (WRI) Climate Analysis Indicators Tool (CAIT), emissions are highly concentrated among 7 countries and the European Union (EU),[11] which enhances the prospect for significant action to be taken outside of the UNFCCC framework.[12] This grouping also includes emitters with the greatest potential for future emissions growth.

Figure 3. Transport Emissions by Country



Source: WRI/CAIT, 2009.

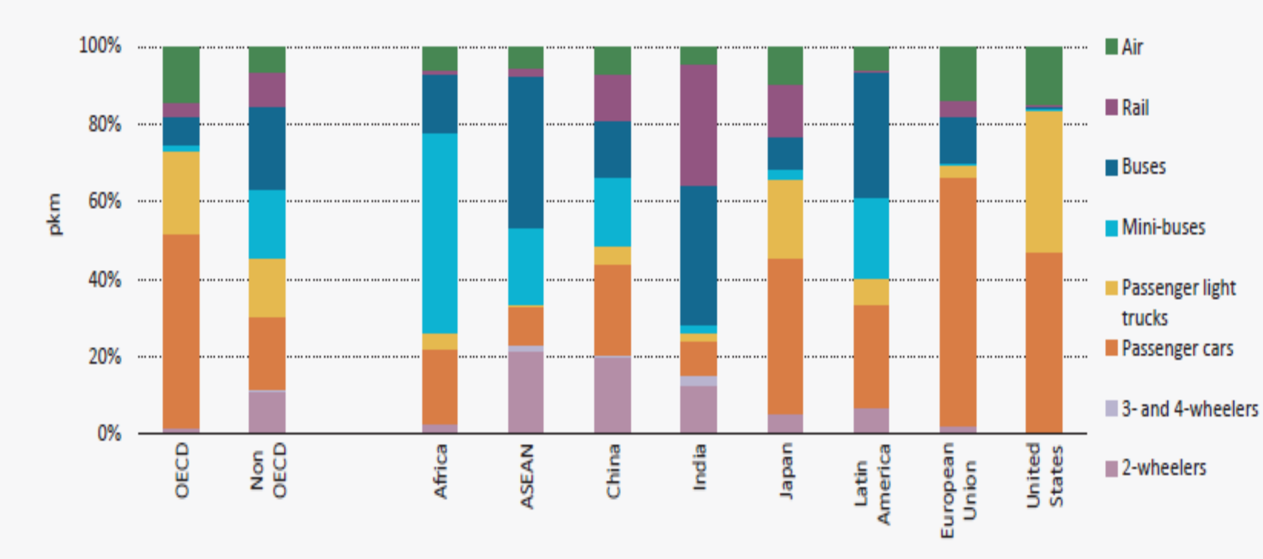
[8] OECD/IEA, 2012 and UNFCCC, 2009.
[9] OECD/IEA, 2012.
[10] OECD.org, 2014.
[11] This discussion will treat the European Union as a single entity, and will include figures for 28 member countries.
[12] UNFCCC 2009.

These top 8 emitters, in order of magnitude, were collectively responsible for 71% (3876 $MtCO_2e$) of global transport sector GHG emissions (5463 $MtCO_2e$) in 2009.[13] The United States and China ranked as the two highest-emitting countries within transport, collectively taking a 38% share of global transport emissions.[14] The United States, which emitted a 29% share of global transport emissions, was followed by the European Union, which accounted for 22%.[15] Though India is only responsible for about a 3% share of emissions from transport, transport is one of India's fastest growing sectors.[16] By 2025, it is projected that India's fleet of vehicles will double to 250 million.[17] For these reasons this report will focus on the United States, the European Union, China, and India.

Though OECD countries currently produce the most emissions from transport, the pace at which future transport sector emissions grow will largely be determined by the decisions made about transport system infrastructure investments in developing countries. The mix of transport modes in various countries varies significantly, as Figure 4 below demonstrates. Current transport mixes are much more diverse in developing countries. Public transport modes make up a larger share of regional motorized transport mixes in Africa, Latin America, and ASEAN countries, and China and India. In general, public transport in the form of rail, bus, and mini-bus comprises a much larger share of motorized transport in non-member OECD countries. Finally, 2-wheeled transport among personal-passenger modes also comprises a much larger percent of overall motorized transport among non-member countries, with particular emphasis on China, India, and Japan, and in ASEAN-member countries in general.[18]

[13] WRI/CAIT, 2009.
[14] Ibid.
[15] Ibid.
[16] Ibid.
[17] ICCT, 2014.
[18] ASEAN member countries include: South Korea, Indonesia, Thailand, Malaysia, Singapore, the Philippines, Vietnam, Myanmar, Brunei, Singapore, Laos.

Figure 4. Motorized Passenger Travel Mode Share, 2009



Source: OECD/IEA, p. 426.

FUTURE PROJECTIONS

Projections for growth in transport demand reflect the exponential increase in urban area spread over the past century; thus, congestion and idling will continue to be central issues in transportation planning as demand for LDVs mobility increases within cities.[19] Emissions related to transport are projected to increase 40% from 2007 to 2030 given current trends.[20] Global passenger and freight travel is expected to double from 2010 figures in the next 40 years, with non-OECD member countries composing 90% of global travel increase.[21] If policy decision-making continues to favor short-term economic gains, energy consumption in the transport sector will grow by 80% due to increased global demand for mobility in rapidly developing economies like China and India.[22]

The United States uses cars and light trucks for over 80% of passenger transport, while in the EU and Japan these transport modes are closer to 60%.[23] If China's and India's transportation systems are evolving in line with OECD planning trends, implying carbon-intensive modes of transport and inefficient growth patterns, this could have a significant impact on global emissions.

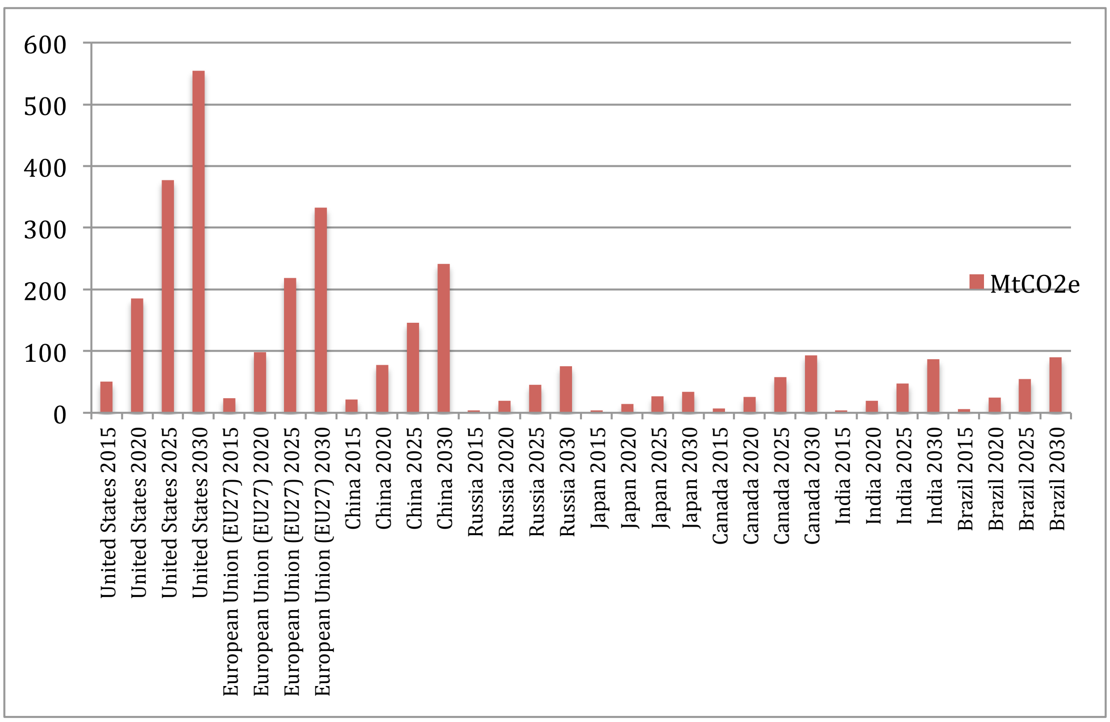
Trends in light-duty vehicle (LDV) sales during the last decade illustrate this shift in transport demand growth, particularly in relation to personal passenger mobility.[24] While U.S.

[19] OECD/IEA. 2012.
[20] ITF, 2010.
[21] OECD/IEA 2012.
[22] Ibid.
[23] Ibid.
[24] Ibid.

vehicle sales halved between 2008 and 2009, China took the lead in worldwide LDV sales. Globally, between 2000 and 2010, annual personal passenger vehicle (PPV) or LDV sales grew from 500,000 in 2000, to 4 million in 2005, and then 12 million in 2010, amounting to a twenty-fold increase.[25] The relative slowdown in OECD member country LDV sales, in contrast to an overall spike in global demand for LDVs suggest that former leaders in LDV sales like the U.S., Japan, and EU members like Germany are reaching a saturation point in terms of PPV ownership and use. Further, the stagnation of growth in LDV sales in EU member countries and Japan can be attributed in part to increased demand for public transport in the last decade.[26]

Most of the near-term abatement potential in the transport sector results from improving the fuel efficiency of light, medium, and heavy-duty vehicles, in addition to the increased use of alternative fuels. Approximately 20% of the global road emissions reduction potential in 2030 comes from improvements to LDVs in the United States alone. The following charts (Figures 5-8) show the potential emissions reductions in 2015, 2020, 2025, and 2030, made by improving transport technology across 7 of the 8 top transport emitters identified using the CAIT dataset. Brazil is also included due to the sizable potential for emissions reductions, especially in LDVs, HDVs and bio-fuels.

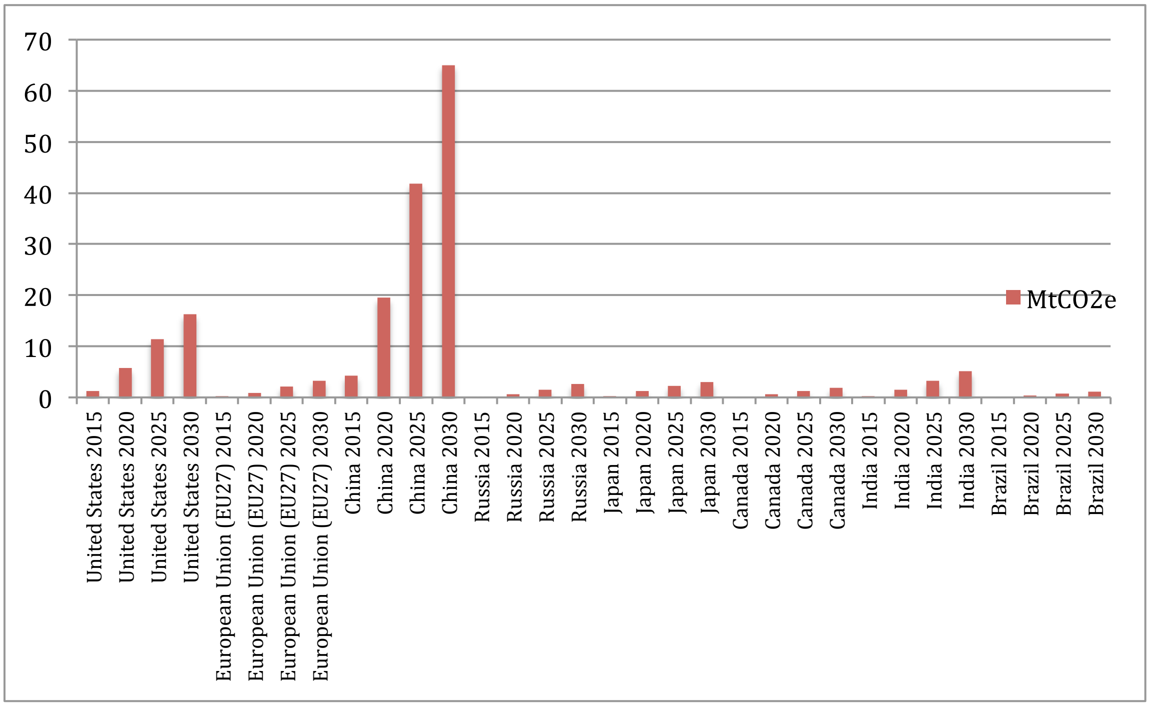
Figure 5. LDV Mitigation Potential By Country



Source: McKinsey Climate Desk, 2009

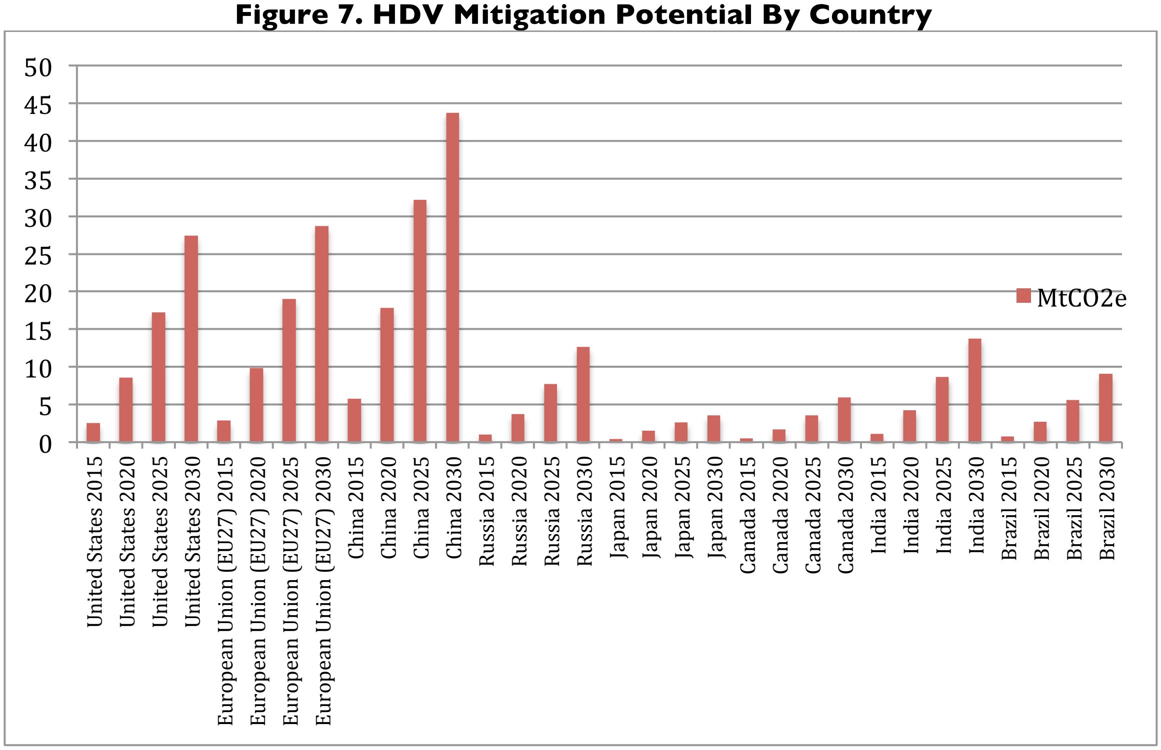
[25] Ibid.
[26] Ibid.

Figure 6. MDV Mitigation Potential By Country



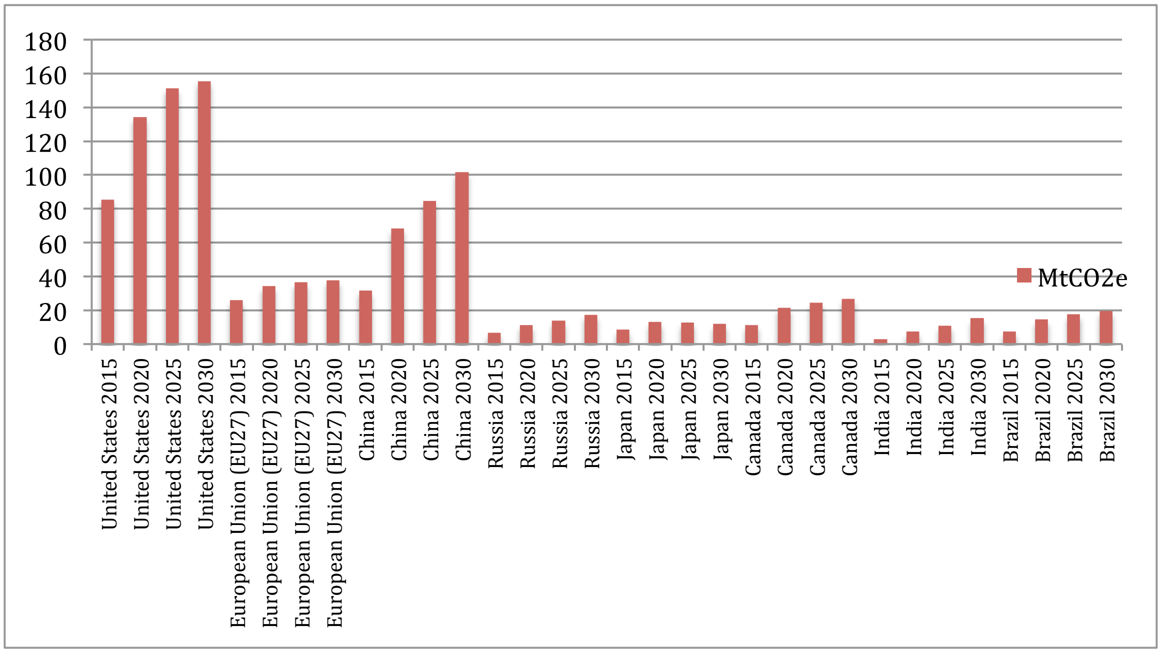
Source: McKinsey Climate Desk, 2009

Figure 7. HDV Mitigation Potential By Country



Source: McKinsey Climate Desk, 2009

Figure 8. Biofuel Mitigation Potential By Country



Source: McKinsey Climate Desk, 2009

Within the market-share of LDVs, which is the fastest-growing mode of transport across the sub-sectors of road, rail, aviation, and maritime, electric fuel cell vehicle technologies have started to make the shift from research and development into the mainstream marketplace.[27] More countries are starting to adopt fuel efficiency and engine combustion standards in line with the EU EURO IV and the U.S. Corporate Average Fuel Economy (CAFE) standards,[28] which may hasten the adoption of other alternatives through a projected price increase for fossil-fuel motorized vehicles.[29] Though maritime and aviation modes of transport have not experienced the same degree of growth that road, rail, and specifically LDVs have in the past decade, each sub-sector figures heavily into the international shipping and transport markets globally. According to the IEA, emissions from international maritime shipping amounted to 1 $GtCO_2$ in 2010, and this figure may double by 2050.[30]

CONCEPTUAL FRAMEWORK

As mentioned previously, emissions from transport make up nearly 15% of worldwide emissions from energy use as of 2010. The lion's share of activity from transport occurs via

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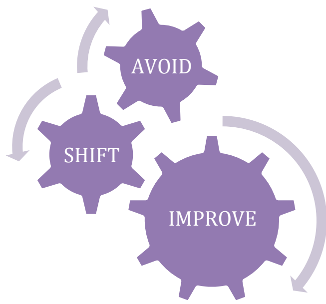
[27] OECD/IEA, 2012.

[28] The EURO V standards and U.S. CAFE Standards are two examples of regulation frameworks that seek to reduce emissions from light and heavy duty vehicles. For more information on these two programs, see EU Environment's page on the EURO V and the EPA OTAQ's site on fuel emission standards (IEA, 2012; EU Environment, 2014; EPA/OTAQ, 2014).

[29] OECD/IEA, 2012; EU Environment, 2014; EPA/OTAQ, 2014.

[30] OECD/IEA 2012.

road travel and increases in per-passenger km traveled.[31] Creating an integrative transport planning process is important, though difficult given the diverse set of actors, venues, rates of development, and perspectives among countries in this sector. Transportation planning is also vulnerable to institutional diversity among governing bodies at the international, regional, national, state, and local levels, which adds further complexity to the issue of implementing interventions for sustainable low-carbon transport (SLoCaT) successfully.[32]



In order to streamline this analysis, the ASI framework will be used to categorize emissions-reducing interventions in the transport space. The ASI framework is the dominant paradigm among the International Energy Agency (IEA), United Nations Environment Programme (UNEP), and other parties developing and advocating sustainable low-carbon transport.[33] Interventions that fall under the **avoid** branch of ASI seek to reduce demand for travel by encouraging users to economize the number and length of trips they take.[34] Avoid strategies also pertain to reducing emissions from transport infrastructure construction and maintenance.[35] **Shift** strategies seek to divert demand for travel from carbon-intensive modes of transport, like fossil fuel burning vehicles, to low-carbon or non-motorized modes of transport.[36] Finally, policies that **improve** current modes of transport speak to increasing fuel efficiency and developing alternative fuel sources to carbon-intensive fossil fuels.[37] In both developed and still-developing economies, ASI strategies promise co-benefits in energy efficiency and production, improved air quality, decreased congestion, and increased access to transport for marginalized communities.[38]

AVOID STRATEGIES

Avoid strategies seek to limit trips, and particularly those that use carbon-intensive modes of transport like LDVs, which play a primary role in GHG emissions due to the aggregate effect of increasing per-person kilometer (km) travel. In fact, the greatest percentage of emissions from road transport comes from LDVs. According to McKinsey, by 2030 there will be 1.321 billion LDVs emitting 4.3 $GtCO_2e$ annually.

Congestion in urban areas has started to reach a saturation point due to increasing rates of urbanization globally. The number of people living in urban areas increased from

[31] Ibid.
[32] SLoCaT.net, 2014.
[33] IEA, UNEP, and GEF are examples of organizations that use a more traditional version of the ASI framework; others, like the ADB and ICCT, use a modified version of it.
[34] Dalkmann, 2011.
[35] ADB, 2010.
[36] Dalkmann, 2011.
[37] Ibid.
[38] OECD/IEA, 2013.

approximately 40% in 1990 to 51% in 2011, and is projected to increase up to 75% by 2050.[39,40] Rising prosperity has coincided with an increase in per-person passenger and freight km traveled.[41] Though this is currently slowing down in OECD countries like the U.S., Japan, and Europe,[42] a sharp increase in demand for transport infrastructure is projected to occur in still-developing countries and China.[43] Shaping current and future demand for travel should thus occur through fiscal incentives and integrated, sustainable urban and transport planning, or travel demand management.[44]

Smart urban growth and sustainable infrastructure also provide co-benefits of equitable economic development and improved quality of life, which will enable SLoCaT reforms in developing and developed economies alike. Despite the latent ability of avoid solutions to deliver steep long-term benefits, visible policy bias has prevented their implementation in many cases.[45] The following section will present the interventions in this space that deliver the greatest emissions reductions while incurring a minimal cost, starting with local level reforms and ending at the international level.

TRAVEL DEMAND MANAGEMENT (TDM) [46]

In the context of Travel Demand Management (TDM), examples of avoid strategies include sustainable land-use planning or transit oriented growth, user fees such as congestion charging and distance-based fees, and freight charging.[47,48] Though data regarding emissions reductions are difficult to find for most of these strategies, the Center for Clean Air Policy (CCAP) circulates a model for estimating the costs and potential emissions reduction potential of many avoid strategies that fall under the TDM paradigm.[49,50]

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[39] Urban areas are defined differently by country and region. For example, in the highly urbanized EU, urban areas are defined by land use. The U.S. Census Bureau, alternatively, defines an urban area as being "Core census block groups or blocks that have a population density of at least 1,000 people per square mile (386 per square kilometer) and surrounding census blocks that have an overall density of at least 500 people per square mile (193 per square kilometer)" (U.S. Census Bureau, 2013).

[40] WHO, 2013; U.S. Census Bureau, 2013.

[41] OECD/IEA, 2012.

[42] According to ETP 2012," average vehicle travel per person and per vehicle in Japan (about 9 000 km per vehicle per year) is far lower than in Europe (about 14 000), which in turn is well below levels in the United States (19 000 per year)." (OECD/IEA, 2012, p.433).

[43] OECD/IEA 2012.

[44] Litman, 2011; GEF/STAP, 2010.

[45] Litman, 2011.

[46] Transportation Demand Management (TDM), Travel Demand Management, and Mobility Management are names used to identify a management paradigm that seeks to optimize the overall efficiency urban transport system through enacting policies that discourage private vehicle use and advocate modes of transport that are more effective, sustainable, safe, and healthy within public transport and non-motorized transport (Broaddus et. al, 2009, 1).

[47] At the Rio Earth Summit in 2012, cities that employed one of or more of these strategies were showcased, with heavy representation from the EU, China, and South Asia (UNCSD/SLOCAT, 2012).

[48] Littman, 2011, 2; UNCSD/SLOCAT, 2012.

[49] For more information on the CCAP Emissions Calculator for Land Use, Transit, and Travel Demand Management, please refer to the following link: http://www.ccap.org/safe/guidebook/guide_complete.html.

According to the CCAP Emissions Calculator, the greatest areas of metric CO_2 emissions reduction potential at default lie in the smart growth[51] of cities as regulated at the state and regional level. This includes fiscal tools and incentives such as, in order of the magnitude of CO_2 emissions reductions possible, pay-as-you-drive insurance,[52] targeted infrastructure spending,[53] road pricing,[54] and green mortgages.[55] Land use policies with the greatest potential include infill/brownfield development,[56] and permitting and zoning reforms.[57]

All of these strategies are incorporated into comprehensive smart growth planning and transit oriented development. Other elements of smart growth and transit-oriented development, as encouraged by TDM strategies, include transit hubs,[58] telecommuting, and internalizing the cost of emissions through fuel subsidy reforms and caps for emissions output.[59] California's Sustainable Communities Law of 2008 is a good example of a pioneering state plan for transportation reform that incorporates the above elements of smart growth.[60] This discussion will delve into user fees and incentives, targeted infrastructure development in developing countries, and internalizing the cost of emissions through fossil fuel subsidy reform and emissions caps in the international transport space.

USER FEES AND COMMUTER INCENTIVES

Congestion pricing, which is a form of road pricing, is calculated as a function of traffic intensity and commuter access.[61] Forms of congestion pricing include area charges[62], which have

[50] CCAP.org, 2014.
[51] CCAP defines comprehensive smart growth as an integrated approach to transportation planning that involves coordination among all stakeholders, and the use of multiple planning strategies to change urban development patterns (CCAPS.org, 2014).
[52] Pay as you drive insurance incorporates vehicle miles traveled and risk factors to provide auto insurance rates to drivers who drive less. (CCAP.org, 2014).
[53] Targeted infrastructure spending is defined by CCAP as the redirection of subsidies to transportation projects that fit within a smart growth platform and avoid sprawl, are not carbon intensive, and that are built using low carbon materials and methods. (CCAP.org, 2014).
[54] CCAP defines road pricing as a pricing structure that applies user fees to balance supply and demand. This can involve targeting congestion, speed, and distance traveled. (CCAP.org, 2014).
[55] Green mortgages are low-rate mortgages provided to homeowners that live in communities that are compact, serviced by public transportation, and that have a mixed land use.
[56] Infill/brownfield development involves encouraging developers to use abandoned or underutilized sites that already exist in an urban area (infills and brownfields) rather than use undeveloped or open space (greenfields) (CCAP.org, 2014).
[57] Permitting and zoning reforms are by CCAP as regulations that encourage mixed-use development to yield more compact, pedestrian friendly neighborhoods.
[58] Transit Hubs are defined as nodes in a multi-modal transit network, often involving rail, road, and other forms of transport, that decrease consumer dependence on personal vehicles and better organize community, regional, and national transport planning systems. (CCAP.org, 2014).
[59] The fiscal incentives of telecommuting are being realized in the private sector, and pose possible benefits in all sectors of transport (road, rail, aviation, and maritime) in terms of passenger transit. (Sustainable Cities Institute, 2014).
[60] CA.gov, 2014.
[61] Litman, 2013.

been implemented in London since the early 1990s, cordon charges,[63] which exist in Singapore and Stockholm, Sweden, and parking and highway [64] fees, which enjoy widespread implementation in the U.S., Australia, and Europe.[65] These fees are implemented in static, variable, and dynamic schedules, which influence demand differently. Of these types of fees, variable area and cordon-based fees have enjoyed the most success in stably shaping demand, as users know what to expect in transit and thus plan their routes accordingly.[66] In its Fifth Annual Report in 2007, Transport for London estimated that CO_2 vehicle emissions were reduced by 16% from 2003 levels in areas where variable or step congestion charging was in effect.[67]

Though congestion pricing serves as the dominant form of demand shaping in transport, distance-based fees have also surfaced as an alternative for flat-rate fees like fuel taxes. In the U.S., the state of Oregon has been testing a weight-distance-based set of fees which add a miles-driven fee to gas purchases based on mileage readings by a station device.[68] Another distance-based fee system was implemented in the Puget Sound area of Washington State and used GPS monitoring to impose tolls and incentives to reduce citizen demand for travel.[69] These programs served as experiments to determine whether distance-based fees could eventually replace federal and state fuel taxes in the U.S., as alternative vehicle technologies become an increasingly mainstream fixture in the automobile market.

In Oregon, over 90% of participants said they would continue paying distance-based fees in lieu of fuel taxes, and the behavioral changes witnessed in the Puget Sound program were significant and projected to have the potential to lead to $28 billion in savings over a 30-year period if implemented over the entire Puget Sound transportation system.[70] Though data on the emissions reduction potential of this and other similar programs are not yet publicly accessible, more research is surfacing on the potential benefits of distance-based fees as a replacement for fuel taxes in the freight sector. For example, weighted distance-based pricing may encourage truck fleet owners to invest in a more sustainable distance-based infrastructure.[71]

User fees can be difficult to enforce, however, and tend to occur in the context of a free-market economy. An example of demand shaping in a more centralized decision making

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[62] Area congestion charges cover an entire geographical area, like a city, and monitoring occurs in the interior of this zone (CMAP, 2013).

[63] Cordon Pricing schemes cover a central urban area, and involve monitoring in the interior and borders of a congestion zone (CMAP, 2013).

[64] Parking fees are designed to regulate demand for travel via increasing charges for parking in an inner city area (Chicago), and highway congestions fees can take the form of tolls that limit the number of vehicles on a given roadway within a given time period (Southern California, Texas, Minnesota) (CMAP, 2013).

[65] CMAP, 2013.

[66] Ibid.

[67] TFL, 2007.

[68] Farzeneh et. al, 2012.

[69] Ibid.

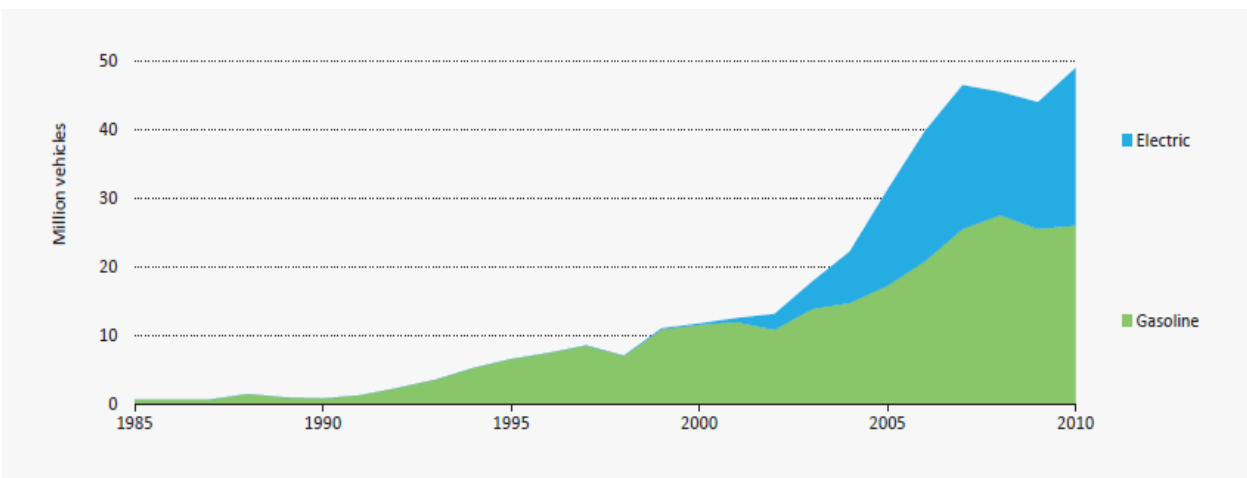
[70] Ibid.

[71] Robinson, 2011.

atmosphere is that of the governments of Shijiazhuang, Beijing, Shanghai, Guangzhou and Guiyang in China enforcing license and vehicle permit lotteries and auctions that restrict the number of drivers based on day of the week and MDV-HDV heavy freight vehicles by hours in the day.[72] Beijing was the first city in China to implement a lottery system due to the pressures of hosting the 2008 Summer Olympics, and this system has spread to 4 other cities.

Concerns of inequity have surfaced, as Beijing and other participating governments implement other congestion-control policies, like a fee and stringent eligibility requirements associated with small vehicle registration.[73] These policies have had some effect on reducing congestion and slowing personal passenger LDV sales, which is important given the fact that these sales have been growing steadily in China over the past decade, with a record-breaking high 20 million automobiles sold in 2013.[74] Electric vehicles, and particularly 2-wheeled motorized vehicles, have witnessed a substantial market share increase as a result of these policies, as demonstrated by the break close to 2008 in Figure 9. Generally, city governments must make a trade-off between decreasing smog-causing pollutants and promoting the economic development of the city.[75]

Figure 9. China 2-Wheeler Sales



Source: IEA, 2012, p. 428

As China continues to develop, expanding population growth in urban and rural areas will place increasing demands on its existing transportation infrastructure. Chinese policy makers will have to make a choice between sustainable transportation demand shaping and quick fixes.[76] This warning echoes in other developing economies in South and Southeast Asia, where megacities have developed according to an old, inefficient transportation planning

[72] Bloomberg News, 2013.
[73] Ibid.
[74] CBSnews.com, 2014.
[75] Bloomberg News, 2013.
[76] ADB, 2010.

paradigm that developed nations like the U.S. and E.U. members are starting to discard. The following section describes how better transportation infrastructure planning in developing countries, where transport demand is projected to increase substantially, contributes to meeting the 2DS by reducing the carbon emissions of construction.

TARGETED INFRASTRUCTURE DEVELOPMENT

In order to meet the needs of increasing global demand for mobility by 2050, which will primarily occur within the personal passenger sub-sector, nearly 25 million paved road km and 335,000 rail track km or an approximate 60% increase in 2010 transport infrastructure will be needed.[77] Rapidly emerging economies like China and India are predicted to invest heavily in broadening the capabilities of road and rail infrastructure, with ASEAN, Latin America, and the Middle East also expected to promote land transport investment increases between 2014 and 2050.[78] Overall, the growing passenger and freight mobility needs of non-OECD member developing countries are expected to account for 85% of projected infrastructure additions over the next 40 years, and expenditures on land transport infrastructure are projected to surpass that of OECD members by 2030, for a total of US$45 trillion USD or 7% of global GDP.[79] Including parking spaces, land transport infrastructure coverage is estimated to be 250,000 km^2 (road) and 300,000 km^2 (rail), which is an area roughly the size of the U.K. and Germany, respectively. The IEA recommends that policies encourage avoid-shift strategies in order to reduce km travel by 20% in 2050 to meet 2DS goals, and to lessen road infrastructure needs by more than 10 million lane-km through shifts to bus and rail modes of travel and land use changes.[80]

Implementation in many cases will be difficult, given the current circulation of political and social biases that paint low-carbon development as expensive development. According to the ADB, low-carbon development infrastructure projects count among the least expensive and difficult to implement, and are more appropriate for low-income people in much of the world who already rely on walking and public transport for mobility.[81] ADB published an evaluation of the potential ways to reduce emissions from land infrastructure projects under its funding in 2010, and found that integrated transportation management under the ASI framework could be an economically feasible way to realize co-benefits in human development, pollution, and emissions reduction, particularly since their long-term benefits promise sustainable results.[82]

ADB is also pioneering using emissions calculators and other tools of analysis and visualization to quantify the costs of their projects, a norm that has spread to other regional development and research entities, like the India GHG program affiliated with WRI. A clear and

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[77] OECD/IEA, 2013.
[78] Ibid.
[79] Ibid.
[80] Ibid.
[81] ADB, 2010.
[82] This project is in line with the ADB's 2020 goals, which involve promoting low-carbon economic development and reducing the carbon footprint of Asian cities (ADB, 2010).

transferrable set of tools for calculating emissions by sector, subsector, and end use is not yet available to the general public, and important figures like transportation per capita emissions by sub-national level are not yet available. As data standards develop in governance, business, research, and development, accessibility to information and to reliable emissions calculators may increase. Please refer to Figure 10 below for an example of ADB work in calculating emission as part of a cost-benefit analysis for project planning.

Figure 10: Estimated Carbon Footprint (Construction + Operations Emissions) of ADB's Road Transport Projects Approved during 2000–2009.

Transport Mode[a]	Total Kilometers Constructed/ Improved	Number of Lanes	TEEMP Footprint Indicator (CO_2 tons/km/lane/year)	Cumulative CO_2 Emissions for 20 Years (million ton)
(1)	(2)	(3)	(4)	(5)
Expressways	5,490	4	1,100	483
Rural Roads	2,893	2	250	29
Rehabilitated Roads	64,621	1–2	15	29
Bus Rapid Transit	13	2	1,100	1
Railways	5,966	1	2,100	251
Metro Rail Transit[b]	0	2	1,200	0
Bikeways[b]	0	1	1.2	0
Total	**78,983**			**792**

Source: ADB, 2010, p.11

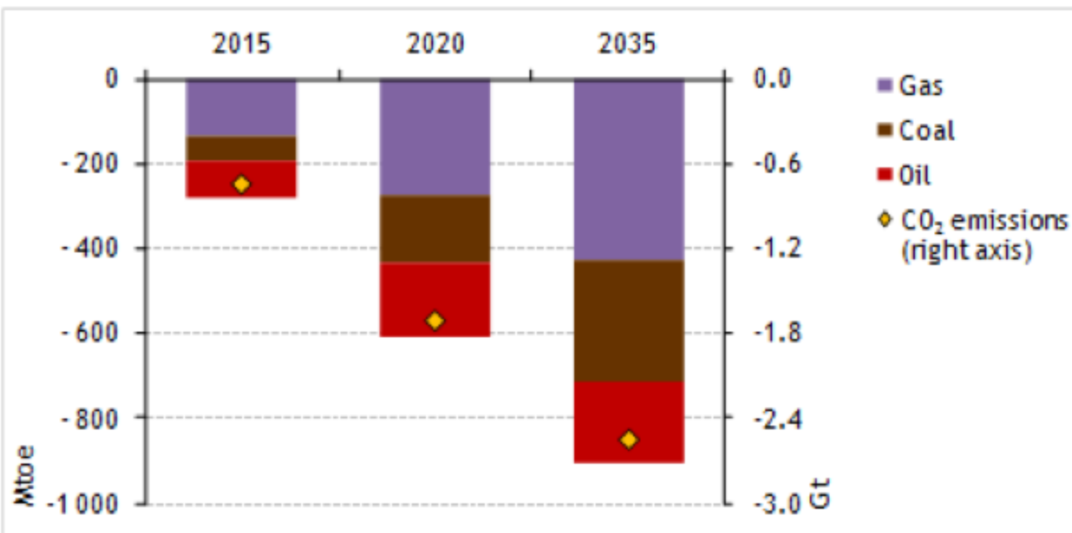
Awareness of the benefits that low carbon or low emission development strategies (LEDS) can provide has started to manifest at higher levels of the international development community[83]. Growing acceptance of these concepts in the international development community speaks to the intersect of human development and climate change, which was first addressed in the public forum in the IPCC's Fourth Assessment Report on Climate Change, and is now an essential part of UNFCCC negotiations.[84] LEDS and low carbon development appear to be a "soft alternative" to implementing GHG emission reduction regulations in some developing countries. Accurate and consistent monitoring and evaluation will present the biggest challenge to the successful implementation of low-carbon construction and planning methods in developing countries, however, and so efforts like that of the ADB to further refine their methods in calculating the "emissions density" of their projects by output, mobility, and investment are important.[85] Currently, ADB has commenced inland waterways, clean bus leasing, sustainable urban transport planning, and railway and logistics efficiency projects in China.[86] Similar projects, which involve BRT, sustainable urban governance and infrastructure planning development, and metro rail projects in Bangladesh, India, the Philippines, Vietnam, Turkmenistan, and Sri Lanka are also in development by ADB.

[83] UNDESA, 2014.
[84] The list of bodies that employ this term is considerable in length, and includes the World Bank, UNEP, UNDP, the EU, ClimateWorks, the Major Economies Forum, the UNFCCC, the IPCC, and the OECD/IEA (UNDESA, 2014).
[85] ADB, 2010.
[86] For more information, please refer to the ADB website: http://www.adb.org/themes/climate-change/transport.

FOSSIL FUEL SUBSIDIES

Inefficiently subsidized fuel has important implications for the transport sector. Fossil fuel subsidies, which totaled US $544 billion in 2012 and exist for oil, natural gas and coal in both OECD and non-OECD member countries, promote the increased and wasteful consumption of energy, drain public funds, and perpetuate existing systems of inequality.[87] The IEA states that redirecting fossil fuel subsidies is one of the main policy action areas necessary to achieve both the 2DS and 4DS by 2050, and could have important implications for reconfiguring the transport sector's fuel mix to include a more diverse, low carbon portfolio.[88] According to IEA estimates in ETP 2011, reducing and eventually eliminating fossil fuel subsidies from 2012-2020 could reduce global energy demand by 4.1% or 620 Million tonnes of oil equivalent (Mtoe) by 2020 as opposed to BAU policies of keeping fuel subsidies as-is, and would continue to a ccrue reduction for a 5% or 930 Mtoe in 2035.

Figure 11. Impact of Fossil Fuel Subsidy Phase-Out



Source: IEA, 2011a.

Serious equity implications surround this topic, as subsidies for dirty fuel sources like coal and oil are advertised as a tool for lifting the poor out of energy poverty.[89] Actual costs of production and distribution are often not made apparent to the consumer, particularly in developing countries where the availability of natural resources determines the degree of a political candidate's support from the public.[90] There is also evidence that fuel subsidies are not

[87] Busby, 2013; OECD/IEA, 2011a.
[88] OECD/IEA, 2012.
[89] Dolan, 2013.
[90] OECD/IEA, 2012.

having a direct impact on increasing the incomes and purchasing power of the world's poor.[91] According to the IMF, the top fifth of households in areas where substantial fuel subsidies are in place typically receive 61% of the subsidies' benefits, while the poorest sectors of society, who the subsidies are engineered to help, receive 3-19% of total benefits.[92]

Though G20 members agreed to a peer-reviewed fossil fuel subsidy phase out, serious implementation problems remain due to the fact that the G20 lacks enforcement capacity.[93] As mentioned previously, subsidies for coal, natural gas, and electricity intersect uncomfortably with political stability in many countries, particularly China, India, and many areas of the Middle East and Latin America. In addition, issues of membership in the G20 and IEA prevent complete implementation. Iran, for example, provides nearly 15% of consumption-based subsidies. Finally, many of the major oil-producing economies also subsidize fossil fuel the most, counting for 75% of total consumption based subsidies, with 34% of this originating in the Middle East.[94]

INTERNATIONAL EMISSIONS FROM TRANSPORT: CAPS AND TAXES

International transport was first treated as a separate entity from country emissions in the 1999 UNFCCC Copenhagen Agreement.[95] The primary modes of international transport are aviation and maritime and it is currently one of the fastest growing sources of GHG emissions due to increases in passenger and freight mobility.[96] Further, maritime, aviation and land-based traffic due to trade and commerce and tourism compose one of the fastest growing sources for GHG emissions globally. Emissions from international transport ranked sixth behind China, the United States, Japan, Russia, and Canada as a global source of GHG emissions in 2011 and 2012 according to the EDGAR database, moving from 1.04 to 1.06 megatonnes of CO_2 equivalent annually.[97]

The Kyoto Protocol (KP) also stipulates that Annex 1 nations reduce or limit their GHG emissions from bunker fuels.[98] Enforcement of this decision in Kyoto has largely occurred through the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), with mixed results.[99] Current updates to the Kyoto decision on bunker fuels include recommendations by the Subsidiary Body of Scientific and Technological Advice (SBSTA) that the quality standards of emissions reporting should increase.[100]

As part of its climate action plan, the European Union advocates a monitoring, results, and verification (MRV) approach to reporting emissions from maritime bunker fuels and also

[91] Busby, 2013.
[92] Ibid.
[93] Busby, 2013.
[94] Ibid.
[95] UNFCCC, 2009.
[96] EDGAR, 2012.
[97] Ibid.
[98] UNFCCC, 1997.
[99] Ibid.
[100] UNFCCC, 2007.

has an emissions trading system (ETS) in place to hold state actors accountable for their GHG emissions over the EU airspace (though the ETS system is currently stalled).[101] These efforts have been met with considerable pushback from developed countries like the U.S. and emerging economies like China, who have challenged the ETS system under international law.

BARRIERS TO IMPLEMENTATION

Applying user fees and encouraging low carbon infrastructure development through better planning and information accessibility promises benefits in trip reduction, but issues of inequity among socio-economic and demographic groups within the United States, European Union, China, and India has the potential to undermine access to safe, low carbon transport for marginalized groups. Further, some part of the cost of transport infrastructure is also subsidized through tax mechanisms that vary by country. For example, in the United States, 70% of funding for highways comes from tolls and other user fees, the U.S. Highway Trust Fund, and revenue from motor vehicle registration and fuel taxes.[102] Development organizations like the World Bank and Swiss Development Bank also channel funding to highway construction in India, and state-level policies regarding user fees vary considerably.[103]

Implementing policies to limit trips has and will continue to face challenges of enforcement, particularly within the decentralized decision making schemes of the United States, India, and the European Union. Similarly, developing consensus among stakeholders in developed and developing countries is a time-intensive process.[104] If policies to encourage better planning do not arise from an explicit agreement among stakeholders, then pushback can be considerable. Further, the institutional structure of governance that exists within a specific country context is important. For example, though India and the United States possess vastly disparate rates of per-capita emissions from transport, both countries possess a democratic political nature that is based on a republic of states. The European Union lies on a similar end of the spectrum, whereas China's decision making is more centralized, which has a positive impact on enforceability.

RECOMMENDATIONS

As the European Union and the United States reach a saturation point in terms of urban and highway congestion, public awareness campaigns regarding the benefits of reducing personal passenger transport in dirty-combustion LDVs increased, and enacted a long-term impact on transportation and urban planning.[105] More major metropolitan areas in the United States are implementing TDM strategies that include congestion pricing on highways and parking. Re-

[101] EU Climate Action Plan, 2014.
[102] US DOT, 2014; Boske, 2013.
[103] World Bank, 2014.
[104] ADB, 2010.
[105] US DOT, 2014.

imagining fuel taxes as reflecting the true cost of a user's travel through the implementation of distance-based fees could also be an effective means of shaping demand for LDV passenger travel as suggested by the Puget Sound study.

Information on the emissions reduction potential of shift strategies is currently limited, and so the second recommendation of the avoid discussion is increasing the flexibility of emissions calculators to generate information in a standardized way for policy decision makers and citizens. Though the impact of increased access to information is still being evaluated, there is some evidence of uptake among stakeholders in the EU and India and in the international development community, with some effect on the United States and China. Further, GHG emissions calculator tools should be standardized and made accessible to the public. Standardizing these tools may increase the availability of information on sub national and regional totals that are not readily disaggregated by WRI, IEA, EDGAR, and McKinsey databases and toolsets.

Developing sustainability certification for transport systems could pose an alternative way to shape behavior in transport infrastructure construction and maintenance. The U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED) certifications proved an effective tool for incentivizing environmentally friendly building construction. The Institute for Sustainable Infrastructure's Envision certification for civil infrastructure could provide the same sort of incentive for transport infrastructure, but a transport specific sustainability certification may be necessary. In either case, the Green Building Council's model of a global network of national and local level chapters is worth emulating.

At an international level, finding the appropriate forum for a compact regarding the phase-out of fossil fuel subsidies is key. Fossil fuel subsidies, particularly in developing economies, may make the penetration of green technologies more difficult by virtue of their presence, and near-complete enforcement worldwide is central to the phase out policy's success. Another recommendation is for shifting the venue for enforcing the phase-out of inefficient fossil fuel subsidies shift from the G20, which has a poor track record of enforcement, to a venue that resembles the IEA, or the IMF, which holds leverage in that it is an important source of funding for many countries.[106]

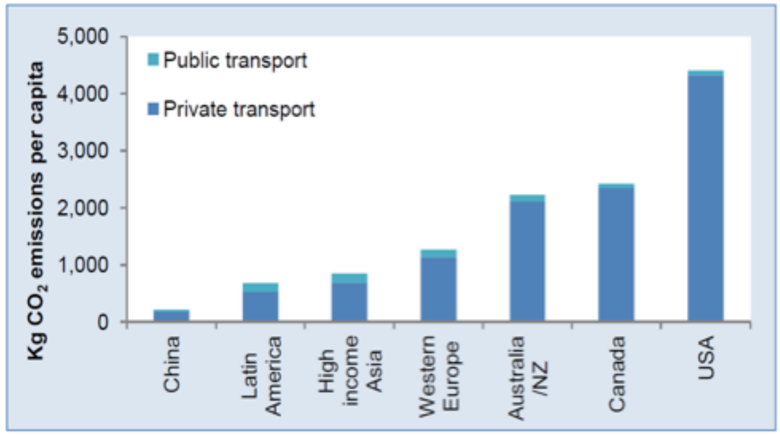
SHIFT STRATEGIES

While avoid strategies contribute significantly to emissions reductions in the transport space, contemporary societal and economic patterns of growth demand a high level of mobility for goods and people. Thus, shifting as much of this necessary travel to low carbon and congestion-reducing technologies will play an important part in the transport sector's contribution to reaching the 2 Degree Celsius Scenario. One of the most visible ways of reducing transport emissions-per-capita is shifting user demand for passenger and freight

[106] Busby, 2013.

mobility from road to rail. BRT is a good example of a transition or interim strategy for shifting public ridership demand from road to rail.

Figure 12. Per-Capita Emissions



Source: Sakamoto et. al., 2010

Other shift strategies that fall under the TDM paradigm include a general advocacy of increasing ridership in public transit, public bike schemes, rail-based mass transit, and promoting pedestrian behavior.[107] As the above figure illustrates, there is evidence that the majority of per-capita emissions come from private passenger travel, and so encouraging increased ridership in public transportation modes like freight and BRT will be key to reducing emissions. No transport technology has changed the pattern of emissions in the transportation sector more than personal passenger vehicles (PPVs). In the past, this change was felt most strongly in North America, as the percent of public transportation's market share decreased with the rise of personal passenger mobility demand in United States. In the future, however, increased demand in developing countries is the biggest projected source of future emissions in the transport sector. In this vein, shift strategies disaggregate into two distinct categories: investments into transportation infrastructure itself and investments into promoting the use of transportation alternatives.

SHIFTS IN FREIGHT

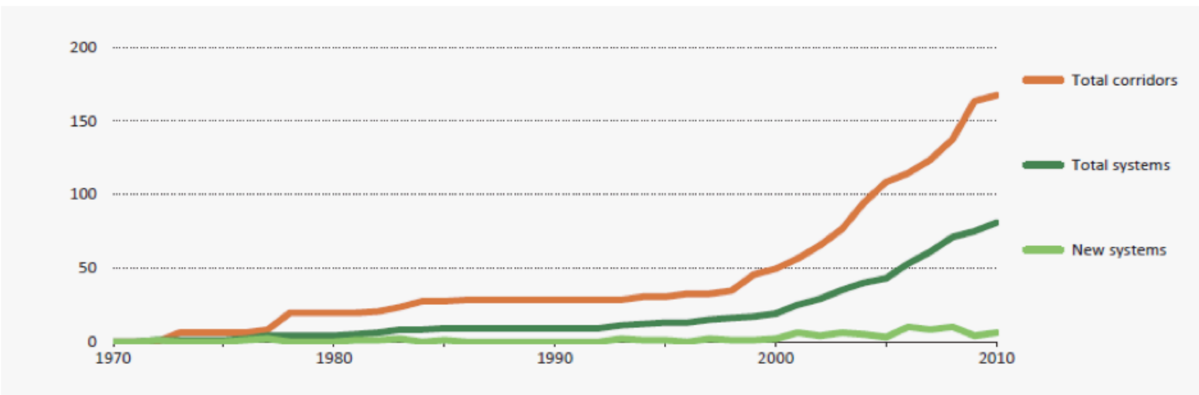
There is modest potential for behavior change in freight, which mostly involves medium and heavy-duty vehicles (MDVs and HDVs). Despite the challenges of finding alternatives to road freight, significant reductions can be achieved, as 97 million MDVs will be emitting 1.5 $GtCO_2e$ and 45 million HDVs will only be emitting 2.3 $GtCO_2e$ annually by 2030. While making up a much smaller share of the overall emissions picture, reducing the number of MDVs and HDVs on the road can still have an impact as these vehicles generally rely on "dirtier fuels" to propel their heavy weight. Additionally, challenges of measurement and enforcement will be reduced, considering that regulating a corporation can be less difficult than managing the behavior of an entire population of private citizens.[108]

[107] UNCSD/ SLoCAT, 2012.
[108] Boske, 2013.

BUS RAPID TRANSIT (BRT)

BRT systems have been increasing steadily in the past decade, and particularly in developing countries in Asia and Latin America.[109] A BRT complex involves high-capacity buses that run in private, bus-only corridors in a manner similar to a metro system; in fact, many compare BRT to an aboveground subway.[110] BRT systems are projected to increase by 3,000 trunk km by 2025, but due to the substantial investment required for BRT-specific infrastructure, it is not clear how much BRT demand will grow beyond this point. Additionally, BRT infrastructure is sometimes utilized as a transitional phase while a city develops its rail system, as is the case in Istanbul. The IEA estimates that a 0.05 $GtCO_2e$ reduction could occur from 2010-2050 if BRT systems continue to grow at a rapid rate. Figure 13 illustrates growth in BRT systems worldwide from 1970-2010.

Figure 13: Timeline of BRT system growth, 1970-2010.



Source: OECD/IEA, ETP 2012, p. 440

With respect to the major economies, BRT systems are highly utilized in Brazil, Turkey, and China. These countries have 11,962,888, 750,000, and 3,978,250 passengers per day, respectively.[111] Despite these high numbers, these are still relatively small portions of overall commuters in each of these nations. Interestingly, BRT has shown a great amount of promise in low-income North American cities, such as Cleveland, Ohio.[112] This system has proven to be significantly cheaper than subway and light rail expansion, as it draws upon existing ground infrastructure, and does not require the significant upfront investment of rail mass transit.

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[109] OECD/IEA, 2013.
[110] OECD/IEA, 2012.
[111] Embarq BRT, 2014.
[112] Metropolitan Planning Council, 2014.

DEVELOPING DEMAND FOR RAIL

As discussed previously, global rail travel is projected to increase two-fold by 2050 in the 4DS modeled by the IEA, especially in emerging economies like China and India that are assuming a more prominent role in international trade.[113] This approximate 23 trillion passenger-km (pkm) annual demand will require a 30% increase in rail infrastructure from 2010 levels.[114] High-speed rail (HSR) projects, many of which are already under construction, will account for 30,000 of the 350,000 km increase projected for 2050. By region, China and India will account for 25% of this demand for new infrastructure, and OECD North America, OECD Europe, Russia, and Latin America will account for the remaining projections.[115]

Increased demand for rail transport will not equal projected demand for road travel in both the passenger and freight categories.[116] However, urban centers in rapidly developing countries like China are investing in high-speed rail as a means to reduce congestion and improve air quality.[117] This policy tendency to opt for investment in rail occurs in areas where threats to public health demand that governments make long-term investments at the expense of short-term losses. If this tendency to make the right decision can be extended to conditions less stressful for humans and the physical environment, it will play an important part in the shift strategies necessary to achieve the 2DS.

Container shipping continues to make rail and maritime shipping relevant.[118] Continuing to shift the freight supply chain from land-reliant MDVs and HDVs to maritime and rail infrastructure is a potential way to achieve greater reductions in emissions, as both water-based and rail-based modes of transport typically employ more efficient combustion technologies that burns less fuel per unit of weight, in comparison with modes of transport like aviation, which burn fuel at a faster rate in order to move cargo into the air.[119]

ELECTRIC VEHICLE SUBSIDIES AND INFRASTRUCTURE (EVS)

Shifting demand to low-carbon modes of road transport has been slow, but fiscal incentives have emerged that encourage consumers to purchase EVs worldwide.[120] These incentives include a $7,500 federal tax credit for EVs in the U.S. as established by the Energy Improvement and Extension Act of 2008, and expanded by the American Clean Energy and Security and American Recovery and Reinvestment Acts of 2009.[121] Similar percentage-based and flat-rate tax rebate programs, subsidies, and penalties have come to fruition in many

[113] OECD/IEA, 2013.
[114] Ibid.
[115] Ibid.
[116] OECD/IEA, 2012.
[117] GEF-STAP, 2010.
[118] Seas at Risk, 2010.
[119] GEF-STAP, 2010.
[120] Fuel Economy.gov, 2014; Teslamotors.com, 2014.
[121] Fuel Economy.gov, 2014.

member countries of the EU,[122] China,[123] India,[124] Japan,[125] and Canada[126] for electric[127] and alternative fuel vehicles.[128] Investing in charging infrastructure for EVs has also been subsidized in the U.S. to both homeowners and businesses through 2013, with the possibility of extension.[129] Sources of private investment take the form of companies like Silver Spring, which is working to help EV suppliers integrate EV infrastructure into the Smartgrid[130].

In the same way that it has revolutionized urban planning, California has played a pivotal role in generating policy norms in the green transport space. The state's Low Carbon Fuel Standard, which took effect in 2011, provides a more competitive market for electricity and alternative fuels through the creation of tradable credits that incentivize transportation and energy stakeholders to collaborate in order to meet the state's 2020 emissions goals.[131] The benefits of this policy touch all parts of California's energy supply chain, and have inspired similar policies in proximal partners like Canada, and others, like the United Kingdom. Other local or state-level initiatives in the U.S. and India, which have strong state-level governance, may benefit from similarly structured initiatives for comprehensive infrastructure reform.

BARRIERS TO IMPLEMENTATION

The existing transport infrastructure of each nation also determines the context in which they implement their emissions reduction strategy. The United States, for example, has an extensive interstate highway system but very little in the way of rail passenger options. In a pure physical sense, this would indicate that the United States has a great amount of shift potential from road to rail. The European Union, on the other hand, already possesses an extensive passenger rail system that connects almost every city. Since this infrastructure is present, and is already widely utilized, there is much less space for gains to be made by shifting to rail.

[122] 15 of the 27 EU member countries currently have policies that provide tax rebates and subsidies for alternative fuel cell and electric vehicles. In addition, 17 of the 27 member countries also levy a carbon tax (EU Climate, 2014).
[123] As of 2010, the Chinese government was piloting a tax rebate program that returned the equivalent of $7,000-$1,000 USD to consumers purchasing electric battery and plug-in hybrid vehicles (Teslamotors.com).
[124] India currently levies a black carbon tax, and seeks to put 7,000 EVs on the road by 2020. Part of this initiative includes subsidizing the only domestically produced EV, the Mahindra Reva (The Economic Times, 2013).
[125] Japan currently implements tax incentives through exemptions from the acquisition, road, and weight taxes (Teslamotors.com).
[126] Canada supports a diverse set of subsidies through the governments of Ontario and Quebec (Teslamotors.com).
[127] Includes battery and plug-in vehicles (Teslamotors.com).
[128] Teslamotors.com, 2014.
[129] Teslamotors.com, 2014.
[130] Silver Spring is a Smartgrid solutions company. For more information, please refer to http://www.silverspringnet.com/solutions/electric-vehicles/#.Uvdwfvl1xRY (Silverspring.net, 2014).
[131] CA.gov, 2014.

Population density plays a large role in the feasibility of transportation strategies. For example, China has found great success in shifting drivers from carbon intensive travel by heavily subsidizing its high-speed rail network. The European Union and Japan have also seen similar success, but this strategy has never been attempted in the United States or Canada. While there may be issues of political will or the pervasiveness of car culture, one of the main factors for success in shifting to rail is the density of the region. The only area of the United States that approaches the densities of these nations is the Eastern Corridor, stretching from Washington, D.C. to Boston. This corridor contains about 17% of the U.S. population but less than 2% of the nation's land area, with a population density of 931.3 people per square mile (359.6 people/km^2), compared to the U.S. average of 80.5 per square mile.[132] While most of the landmass of North America will not see high-speed rail anytime soon, this corridor has great potential for rail shifting.

Social factors also contribute to user preferences in transportation demand. One of the most obvious is the North American "car culture." Since the United States modernized around the automobile, most of its cities (and nearly all of its new ones) are most easily navigated by car. More Americans live in suburban areas than in other developed countries, which places them on average much farther away from their place of work. The United States has more cars in ratio to its population than any other nation on Earth. More importantly, the newly rich in developing countries across the world are emulating this car culture, with multiple cars being equated with elevated social status. This is a disturbing trend, given the rising standards of living in developing nations and the fact that their cities are already highly congested and choked with pollution. Leaders in both developing and developed nations are realizing the increasing challenges that car culture creates. Petro Gustavo, the mayor of Bogota, is encouraging a new measure of development, when he said, "a developed country is not a place where the poor have cars. It's where the rich use public transportation."

Another major factor in addressing emissions reduction in the transport space is the ability of each country to shape the behavior of its citizens. Out of the countries included in this study, China is by far the most authoritarian and has the greatest ability to make sweeping behavioral changes in a timely fashion. Most other nations are forced to use less direct methods, including tax policies and subsidies.

RECOMMENDATIONS

Though there are many institutional factors that encourage the use of carbon-intensive road infrastructure, demand for less carbon-intensive transportation can be generated through two main strategies. First, significant investments in BRT, light rail, subway, and inter-city high-speed rail could provide significant emissions reductions by 2030. Great potential for reductions in the United States currently exists, as many metropolitan areas have no significant low carbon transport options and there are no high-speed rail linkages between cities. The European Union

[132] Short, 2007.

is already saturated with diverse low carbon transport options and high speed linkages between cities, but increasing the emphasis on providing fiscal incentives for EV infrastructure could increase demand for EV and hybrid vehicles in EU member states where market penetration has not reached its full potential. Part of this recommendation also includes encouraging investment in transit hubs in the major metropolitan areas of the U.S., China, and India, which would encourage multi-modal travel relying on public transit.

In China, national, state, and local governments are all making significant investments in low carbon infrastructure, so they already seem to be on the path to taking advantage of the shift strategy. It remains to be seen if their investments will be able to keep up with the increased transport demand of the Chinese populace. India is on the verge of a major increase in transportation demand, and just like China it remains to be seen whether the government will be able to get ahead of the curve or not. Up until this point, India's low wages have forced most to use less carbon intensive methods, but rising incomes will see a greater demand for carbon intensive methods and the government has yet to implement any measure to counter this trend.

The second policy recommendation of this discussion on shift strategies is that of reframing the pitch for less carbon intensive transport as being beneficial to improving the quality of life. There is a major collective action problem attached to advocating the behavioral changes necessary to reach 2DS as individual stakeholders do not feel responsible for the overall share of emissions. In addition, each major emitting economy has its own unique transport challenges, and most global recommendations fail to take this into account. We recommend that governments and emissions reduction advocates concentrate on framing their policies less on abstract reduction targets and more on tangible quality of life increases. Instead of considering the main goal of these strategies to be emissions reduction, air quality, congestion, travel time, and personal cost should be the centerpiece of the argument. This approach is likely to be appealing to local and state level governments, as well as private citizens, as they will feel the immediate effects on their quality of life, as opposed to the climactic effects of emissions, which take time to manifest.

IMPROVE STRATEGIES

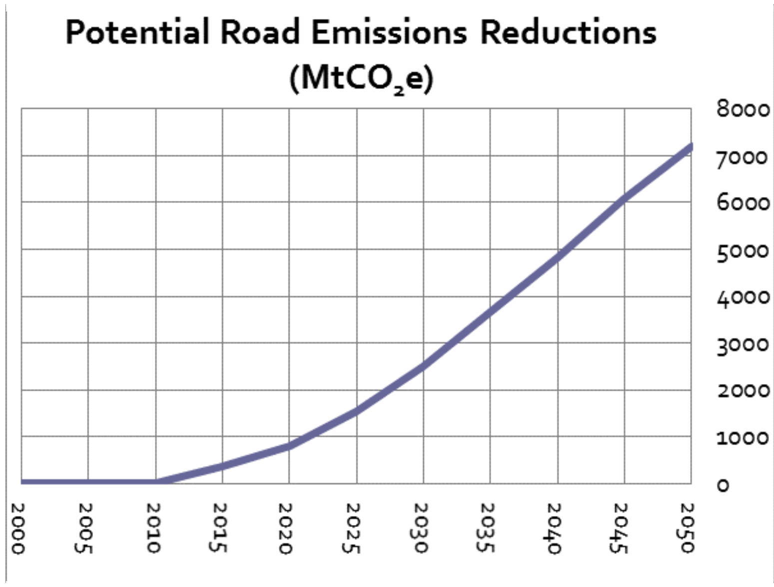
The "Improve" category accounts for the bulk of mitigation potential in the transport sector. Globally, the IEA projects that road emissions alone can be reduced by 2.5 $GtCO_2e$ in 2030 and 7.2 $GtCO_2e$ in 2050.[133] Global emissions reductions from improved efficiency of road, sea, and air transport modes, and the displacement of fossil fuels with cleaner alternatives, will amount to 3 $GtCO_2e$ in 2030, according to McKinsey.[134] This comprises 8% of the total abatement potential across all sectors, in 2030, of 37.8 $GtCO_2e$. While the emissions reductions possible in the transport sector are sizable, keeping pace with the rapid and

[133] OECD/IEA, 2012.

[134] McKinsey & Company's Climate Desk is a tool that calculates the economic implications of climate change mitigation strategies on countries and the global economy by sectors and technologies (Climate Desk, 2009).

aggressive adoption of new transport technologies and alternative fuels that McKinsey assumes in their models will be challenging. Carefully planned policies will be needed to accelerate the adoption of more efficient transport technologies and alternative fuels.

Figure 14. Potential Reductions in Road Emissions



Source: IEA ETP 2012 Data

McKinsey's models provide detailed information on the transport technology improvements that need to be incorporated into transport modes, to produce the emissions reductions they project. These technological improvements fall into four broad categories: light, medium, and heavy-duty vehicle efficiency gains; air transport efficiency gains; sea transport efficiency gains; and alternative fuel use. LDV efficiency gains are grouped into four progressive stages each for gasoline and diesel vehicles, full hybrid gasoline and diesel vehicles, plug-in hybrid gasoline and diesel vehicles, compressed natural gas (CNG) fuelled vehicles, and electric vehicles. MDV efficiency gains are grouped into four progressive stages each for gasoline and diesel powered models, and HDV efficiency gains are organized into four progressive stages of improvements for diesel-powered vehicles. McKinsey also includes projections for first and second-generation biofuel consumption across LDV, MDV, and HDV classes. Finally, the tool projects combined efficiency gains and alternative fuel use in both sea and air transport to net the emissions savings in those sub-sectors.[135]

LDV, MDV, AND HDV IMPROVEMENTS LEADING TO INCREASED FUEL ECONOMY

LDVs are the most popular mode of passenger transport in OECD countries, accounting for over 70% of motorized passenger travel in 2009.[136] Non-OECD countries are increasingly using LDVs, with one third of passenger travel reported to use this mode in 2009. The United States and European Union have already enacted policies that require vehicle manufacturers to progressively improve the fuel economy of their vehicles. The Corporate Average Fuel Economy (CAFE) Standards for LDVs in the United States are now finalized for vehicle model years 2017-2021, and the National Highway Transportation Safety Administration (NHTSA) is exploring possible standards for model years 2022-2025, leading to fuel economy

[135] Climate Desk, 2009.
[136] OECD/IEA, 2012.

for vehicles in 2025 double that of vehicles sold in 2012.[137] The U.S. EPA also set corresponding GHG emissions standards for model years 2017-2025. These standards are part of the "…national program to improve fuel economy and reduce greenhouse gas emissions…" of light-duty vehicles, which "…build on the success of the Administration's standards for cars and light trucks for Model Years 2011-2016."[138]

Emissions standards for LDVs have been introduced in other countries as well, and usually follow the Euro V model.[139] China and India, in particular, have started to implement fast-tracked, rigorous standards in cities under the China IV and Bharat III standards.[140] India is also applying a carbon tax to encourage the ubiquitous but highly inefficient lorries to be replaced with more efficient vehicles.

In Europe, the Euro V emissions standards went into effect in 2009 and will be superseded by Euro VI standards in 2014. These standards do not limit CO_2 emissions directly, but other exhaust emissions such as CO and particulate matter.[141] By reducing these other harmful vehicle emissions local air quality is improved, and the higher efficiency of the vehicles engineered to meet these standards in turn reduces the CO_2 emissions of European LDVs. Euro and CAFE equivalent standards are increasingly being adopted in developing countries, due to the benefits for local air quality, which reduces the CO_2 emissions of LDVs, MDVs, and HDVs globally.

The first bundle of LDV efficiency improvements, for both gasoline and diesel vehicles, is achieved using technologies that are already found on many newer vehicles today. These include engine friction reduction, variable valve timing, low rolling resistance tires, tire pressure monitoring systems, and slight weight reductions.[142] The second set of LDV efficiency gains come from reducing engine displacement, optimizing gear ratios, improving aerodynamic performance, and incorporating engine start-stop technology to limit idling time. The third stage of LDV efficiency improvements is comprised of more aggressive engine displacement reductions, aerodynamic improvements, air conditioning modifications, torque oriented boost for diesels, and adding regenerative braking systems. Finally, the fourth set of LDV improvements include improving fuel injection systems, reducing vehicle weights by 9%, further reducing engine displacement, and transmission improvements.[143]

CNG fuelled vehicles are not predicted to have a substantial impact on emissions reductions globally, primarily because the market penetration is not even expected to rise to 1% by 2030. Gasoline plug-in hybrid vehicles are predicted to slowly rise to 17% market penetration by 2030[144], with the slower uptake likely due to their higher relative cost, need for

[137] NHTSA, 2012.
[138] Ibid.
[139] ICCT, 2014.
[140] For more information, please see ICCT and Diesel.net's transportpolicy.net, and refer to Emissions Standards and Heavy Duty Emissions for China and India.
[141] Regulation (EC) No 582/2011.
[142] Climate Desk, 2009.
[143] Climate Desk, 2009.
[144] Ibid.

accompanying charging infrastructure, and limited electric driving range. Entirely electric vehicles promise long-term transportation technology, but McKinsey estimates that they will only achieve 2% market penetration by 2030. The most significant barriers to greater electric vehicle adoption are charging infrastructure costs, which limit charging station availability, and limited range, which is constrained by battery technology. The following table summarizes the efficiency gains, market penetration assumptions, and emissions abatement potential McKinsey projects for LDV technology improvements.

Table 1. LDV Technology Improvements

Technology Lever	Efficiency Improvement Over Base	Market Penetration 2011-2015	Market Penetration 2016-2020	Market Penetration 2021-2025	Market Penetration 2026-2030	Cumulative GHG Emissions Reduction Potential ($MtCO_2e$)
LDV Gasoline Bundle 1	13%	20%	20%	1%	0%	38
LDV Gasoline Bundle 2	25%	17%	22%	7%	2%	119
LDV Gasoline Bundle 3	32%	7%	30%	27%	4%	280
LDV Gasoline Bundle 4	39%	0%	12%	37%	54%	590
LDV Gasoline Full Hybrid	44%	3%	8%	16%	22%	314
LDV Gasoline Plug-In Hybrid	N/A	0%	3%	11%	17%	233
LDV Diesel Bundle 1	12%	20%	19%	3%	0%	5
LDV Diesel Bundle 2	20%	20%	27%	11%	4%	8
LDV Diesel Bundle 3	30%	7%	25%	27%	9%	26
LDV Diesel Bundle 4	35%	0%	13%	34%	56%	114
LDV Diesel Full Hybrid	46%	3%	8%	15%	20%	45
LDV Diesel Plug-In Hybrid	N/A	0%	3%	8%	10%	24
LDV Compressed Natural Gas	N/A	0%	0%	0%	0%	6
LDV Electric Vehicles	N/A	0%	1%	1%	2%	29

The first two packages of MDV improvements have surprisingly low mitigation potential in McKinsey's models. In total, the mitigation potential of these four bundles of MDV technological improvements only generate 2-3 $MtCO_2e$ of abatement.[145] This is understandable, because the reduced rolling resistance and improved aerodynamics McKinsey predicts for the first two packages of improvements only improve gasoline and diesel MDV fuel economy by 4%.

The third and fourth packages of MDV improvements McKinsey models consist of further improvements to aerodynamics and rolling resistance, and engine modifications that improve efficiency, including "mild hybrid" modifications.[146] While the fuel economy improvements for MDVs are not as substantial as for LDVs, the significant market penetration that McKinsey assesses as possible is encouraging. The following table summarizes the efficiency gains, market penetration assumptions, and emissions abatement potential McKinsey projects for MDV technology improvements.

Table 2: MDV Technology Improvements

Technology Lever	Efficiency Improvement Over Base	Market Penetration 2011-2015	Market Penetration 2016-2020	Market Penetration 2021-2025	Market Penetration 2026-2030	Cumulative GHG Emissions Reduction Potential ($MtCO_2e$)
MDV Gasoline Bundle 1	N/A	N/A	N/A	N/A	N/A	N/A
MDV Gasoline Bundle 2	4%	30%	10%	0%	0%	1
MDV Gasoline Bundle 3	10%	20%	40%	50%	50%	22
MDV Gasoline Bundle 4	11%	20%	40%	50%	50%	25
MDV Diesel Bundle 1	N/A	N/A	N/A	N/A	N/A	N/A
MDV Diesel Bundle 2	4%	30%	10%	0%	0%	1
MDV Diesel Bundle 3	10%	20%	40%	50%	50%	28
MDV Diesel Bundle 4	11%	20%	40%	50%	50%	31

Source: McKinsey Climate Desk, 2009

[145] Climate Desk, 2009.
[146] Ibid.

The first package of HDV improvements McKinsey builds into their model is based solely on reducing rolling resistance, while the second bundle of HDV improvements is achieved by adding aerodynamic modifications. These easily implemented solutions should provide some immediate emissions reductions until more substantial modifications can be made. The third and fourth sets of HDV improvements incorporate engine modifications, including "mild hybrid" technology.[147] The following table shows the efficiency gains, market penetration assumptions, and emissions abatement potential McKinsey projects for HDV technology improvements.

Table 3: HDV Technology Improvements

Technology Lever	Efficiency Improvement Over Base	Market Penetration 2011-2015	Market Penetration 2016-2020	Market Penetration 2021-2025	Market Penetration 2026-2030	Cumulative GHG Emissions Reduction Potential ($MtCO_2e$)
HDV Bundle 1	3%	30%	6%	0%	0%	1
HDV Bundle 2	7%	30%	14%	0%	0%	4
HDV Bundle 3	9%	20%	24%	25%	20%	32
HDV Bundle 4	13%	20%	56%	75%	80%	153

Source: McKinsey Climate Desk, 2009

AIR AND SEA TRANSPORT IMPROVEMENTS

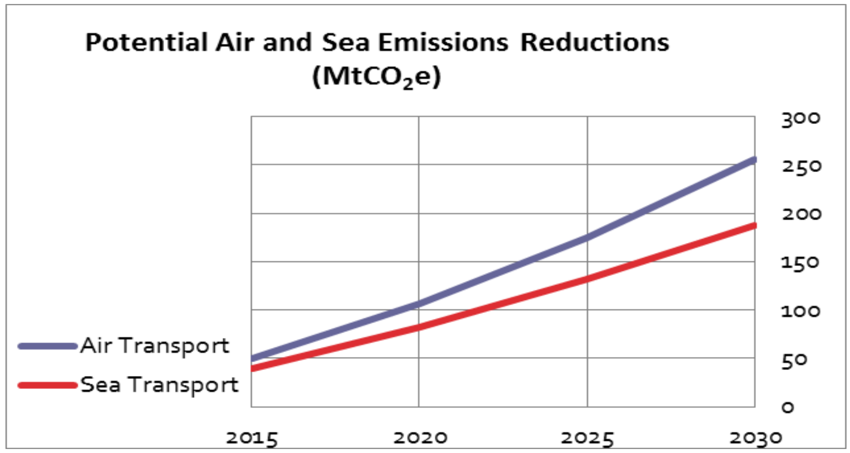
According to McKinsey, air and sea transport can be improved to reduce the emissions contributed by these two largely international modes of transport. The strategies that McKinsey proposes to reduce sea transport emissions include: improving the design of hulls, propellers, and stern flaps of ships to improve their hydrodynamics, or reduce the drag of ships moving through water, optimizing the performance of ship engines, adding waste heat recovery systems to ships, and increasing the size of vessels and reducing the speed at which they travel.[148] With respect to air transport, McKinsey suggests that the technological improvements that can reduce emissions include: aerodynamic improvements, engine retrofits and upgrades, lower-speed flight designs, and accelerated rates of fleet replacement.

In addition to these technological improvements, McKinsey outlines operations improvements that can reduce air transport emissions such as: improved fuel management, optimized takeoff and landing procedures, preventing taxiing with engines powered up, cabin-weight reductions, improved air-traffic management, increased load factors, and the ratio of

[147] Ibid.
[148] Climate Desk, 2009.

aircraft lift to its weight.[149] The table above shows potential emissions reductions from these technological and operational improvements, in addition to the increased use of alternative fuels in ships and planes.

Figure 16. Potential Air and Sea Emissions Reductions by 2030.



Source: McKinsey Climate Desk 2009

The utilization of more alternative fuels in air and sea transport systems should be a central focus of efforts to reduce emissions in these transport modes. Black carbon emissions from Arctic shipping are particularly damaging. According to a recent International Council on Clean Transportation article, since 1890, "black carbon may have increased average temperatures in the Arctic by 0.5 to 1.4 degrees C".[150] Black carbon emissions in Arctic shipping are expected to rise substantially by 2030. Fortunately, relatively easy to implement solutions—such as use of diesel particulate filters or alternative fuels—can eliminate the bulk of black carbon emissions from arctic sea transport. Diesel particulate filters are relatively easy to retrofit onto existing engines, and like Liquefied Natural Gas (LNG) as alternative shipping fuel, they can reduce black carbon emissions by up to 99%.[151] LNG use as a shipping fuel would be a relatively more expensive strategy; due to the infrastructure changes required to equip ports for LNG fueling and the extensive modifications to the fuel storage and delivery systems of ships that would be necessary. International agreement requiring the use of emissions control equipment or alternative fuels to eliminate Arctic black carbon emissions will allow ship manufacturers and operators to find the least-cost solutions best suited to their circumstances. For a more in-depth analysis of black carbon emissions from Arctic shipping, refer to the *Short-Lived Climate Forcers* report.

DISPLACING FOSSIL FUELS WITH ALTERNATIVES

Alternative fuels offer some of the most promising options to achieve near-term transport emissions reductions across all transport modes. McKinsey's analysis includes 1st and 2nd generation biofuel usage in their estimates of possible emissions reductions, but their

[149] Climate Desk, 2009.
[150] Frease, 2012.
[151] ICCT, 2012.

analysis may underestimate their potential. McKinsey does not estimate much biodiesel usage, at only 3.3% of diesel volume in both the BAU and abatement scenarios.[152] Most of the emissions reductions that McKinsey estimates will result from the use of biofuels come from the use of ethanol. McKinsey assumes slightly less than 6% of gasoline volume will consist of ethanol in their BAU scenario and 25% in the abatement case. If 25% of gasoline volume were made up of 1st and 2nd generation biofuels, the emissions reduction potential would reach 455 $MtCO_2e$ in 2030.[153] While some vehicles have been designed to run using primarily ethanol as a fuel, there is a limit to the amount of ethanol blended with gasoline that most vehicles can tolerate. This is commonly referred to as the "blend wall," which limits the proportion of ethanol traditional gasoline engines can handle to 10%.[154] This technical barrier makes achieving the 25% of total gasoline volume target for ethanol less likely.

To meet, or possibly exceed, the aspirations for alternative fuels usage, all existing and emerging alternative fuel technologies must be considered. Various alternative fuels have strengths and weaknesses that can accelerate or impede their adoption. The major factors that affect the rate of diffusion of alternative fuels include their ease of integration into existing distribution systems, the cost of retrofitting or producing new vehicles that can run using these fuels, and their cost of production. Ethanol, biodiesel, methanol, dimethyl ether (DME), and natural gas are a few of the potential fuels that could reduce traditional gasoline and diesel consumption. For instance, recent breakthroughs announced by the University of Southern California's Loker Hydrocarbon Research Institute open the opportunity for producing methanol from $C0_2$ captured from power plant emissions.[155] Carbon Recycling International is already putting this technology to the test in a commercial-scale pilot plant. Methanol can also be made from natural gas, which may make it easier to fuel vehicles using new natural gas sources, since methanol is a liquid fuel that is easier to incorporate in existing fuel distribution systems. By opening up fuel markets to competition from all alternative fuels, emissions reductions from reduced fossil fuel consumption in the transport sector can be maximized.

BARRIERS TO IMPLEMENTATION

Improving the fuel economy of LDVs and MDVs should be relatively easy to achieve now that the US and EU are mandating such improvements. Many of the vehicle improvements that McKinsey outlines are already being incorporated into new vehicle models in the US and EU, or are planned for the near future. By using the same top-down regulatory approach, such as setting corporate average fuel economy standards, the prospects for adoption of these technologies in developing countries are improved since vehicles are already being designed to meet these requirements in other markets. Regulators should be able to manage this easily due to the small number of firms manufacturing vehicles. In addition, fuel economy standards will pressure vehicle manufacturers in developing countries to adopt more efficient technologies.

[152] Climate Desk, 2009.
[153] Climate Desk, 2009.
[154] EPA, 2013.
[155] Perkins, 2013.

Because this can be achieved easily through joint ventures with major vehicle manufacturers, the political opposition smaller vehicle manufacturers pose should be minimal.

The lower operations costs of more fuel-efficient vehicles offset the cost of all but the most expensive technologies, like plug-in electric vehicles. Because the individuals operating most LDVs and MDVs own them and bear the cost of fueling them, those making the decision on what vehicle to purchase capture the fuel savings of new technologies. This should make the adoption of fuel-saving vehicle technologies by consumers proceed rapidly. The same is not true for HDVs.

McKinsey's projections for the fuel economy improvements possible in HDVs appear quite conservative, but that is appropriate given the barriers to implementation of fuel saving technology for HDVs. As a joint North American Council for Freight Efficiency and International Council for Clean Transportation (ICCT) report in 2013 concluded, some of the most significant barriers to increased adoption of fuel-efficient technologies in North American HDVs were uncertain in terms of payback times, the capital investment required, the lack of information about and inconsistency of fuel efficiency gains, and the inability of truck owners to capture operational savings on leased vehicles.[156] Policies to overcome these barriers will be necessary to ensure that HDV fuel economy is improved and emissions from these vehicles can be reduced. While HDV owners may not opt for fuel saving technologies on their own, the same top-down regulatory approach that has been applied to LDVs is viable due to the limited number of engine and HDV manufacturers that standards would need to be applied to.

Air and sea transport improvements offer the same sort of operations cost savings that make the adoption of LDV improvements more likely. Unfortunately, due to the primarily international nature of these modes of transport, an overarching authority cannot impose regulations globally without agreement among many governments. Given that global agreements are inherently difficult to achieve, bilateral of multilateral agreements among major emitters are the best alternative.

Alternative fuels use is an important pathway to decarbonizing transport, but displacing enough fossil fuels will be difficult. Fuels like LNG or electric vehicles require substantial infrastructure modifications to make it into the transport fuel mix. In addition, biofuels production generates externalities that may offset the CO_2 emissions savings and drive up global commodity prices. Technical barriers also prevent use of ethanol in traditional gasoline burning engines at blends over 10%. Emerging alternative fuels may circumvent many technical and cost barriers, but the pace of their development and diffusion must be accelerated by policies that encourage competition among all fuels, with the goal of promoting low-carbon or renewable fuels.

[156] Roeth et al., 2013.

RECOMMENDATIONS

According to the IEA's ETP 2012 report, substantial progress was made toward improving technology for the Transport sector to achieve emissions reductions goals for 2 degree Celsius scenarios. However, the rate of diffusion of these technologies, particularly hybrid and battery electric vehicles, needs to be accelerated. The nature of sea and air transport necessitates policy development and coordination at the international level to reduce emissions, particularly Arctic black carbon which has disproportionately damaging near-term warming effects.

The IEA suggests that the central focus should remain on "…implementing and tightening fuel economy standards for all major markets, to be on a path to reach 4.0 Lge (liters gasoline equivalent)/100km by 2030…for new passenger LDVs on average."[157] MDVs and HDVs should also be regulated by increasingly stringent fuel economy standards, building upon the success of such policies with regard to LDVs. To ensure that hybrid and electric vehicles diffuse as quickly as the IEA projects will be necessary, they propose incentives to adopt these vehicles, such as CO_2 emissions based vehicle and fuel taxes that internalize the cost of externalities associated with burning fossil fuels in internal combustion engines.[158] Increasing taxes on traditional fossil fuels will also enhance the competitiveness of emerging alternative fuels with lower associated GHG emissions. In addition, coordination between local and national government bodies will be vital to ensuring that adequate charging infrastructure is available to users of plug-in vehicles.

To reduce air and sea transport emissions, the IEA supports the establishment of a "global aviation emissions trading system," as well as an efficiency index for sea transport that is supported by incentives to improve efficiency. In addition, cooperative regional regulation of sea emissions, especially in Arctic shipping lanes, are important to controlling pollution in these spaces not under the jurisdiction of any single state. Another important international strategy for reducing transport related GHG emissions is support for R&D investment in emerging technologies. The IEA notes that, "…given the costs of transport systems, vehicles and fuels…current R&D expenditures appear very low".[159]

Public investment in transport research as well as incentives for investing in low-carbon technologies, especially for HDVs, are an important tool to ensure that the future carbon intensity of transport modes is reduced quickly enough to meet global goals. Incentives and support should also be provided for the formation of joint ventures between established global vehicle manufacturers and those in emerging markets. A study of Chinese vehicles showed that those produced in cooperation with global auto manufacturers had significantly lower emissions, higher fuel economy, and incorporated the technologies common on vehicles in markets with strict emissions standards.[160] Increasing the number of such joint ventures in emerging markets will accelerate the pace of adoption of pollution reducing transport

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[157] OECD/IEA, 2012.
[158] Ibid.
[159] Ibid.
[160] ICCT, 2010.

technologies. Coordination between all levels of government and private businesses will build upon the growing success of efforts to decrease Transport sector emissions and ensure that targets for GHG emissions reductions can be achieved.

CONCLUSION

International climate change and emissions conferences like the KP address transport, but it rarely takes center-stage as an issue, and many of the transport-related issues that it addresses, like bunker fuels, have not seen full implementation because most of the major emissions increases will happen in developing countries, which do not have to commit to making any specific emissions reductions. The only major climate change conference in which transportation was a major topic was the Rio Earth Summit, in which governments agreed on a "new reliance on public transportation systems in order to reduce vehicle emissions, congestion in cities and the health problems caused by polluted air and smoke".[161]

A challenge for initiating dialogue about transportation emissions reduction in a global setting is that stakeholders are not individually responsible for their share in generating emissions. Each major emitter has its own unique transport challenges, but countries are united in a desire to protect the welfare of their constituents. Governments and emissions reduction advocates should focus policies less on abstract reduction targets and more on tangible quality of life increases. This approach is likely to be appealing to local and state level governments, as well as private citizens, as they will feel the immediate effects on their quality of life, as opposed to the climactic effects of emissions, which are more abstract and diffuse.

An effective strategy of encouraging the United States to meet emissions standards, for example, would be branding ASI strategies in the context of reducing congestion in major metropolitan areas. The average American commuter now spends a full 40-hour workweek stuck in traffic every year, and this trend is only worsening.[162] This discussion has identified several ways in which the true cost of road transport is masked, either through subsidies or inefficient taxation. Exposing the true cost of road transport, including infrastructure maintenance and congestion pricing, would make many commuters reevaluate their transportation methods. Even if re-framing the relevance of ASI strategies is primarily successful in the United States, there is a significant emissions reduction potential from reducing demand for LDV travel and associated emissions in the United States alone.

Still-developing countries like China and India will respond to co-benefits in air quality from reforms in transport. China will be much more likely to adopt emissions standards because of air quality concerns in major cities like Beijing. Meeting emissions standards is of some concern to China, which primarily results from a need to appease the European Union. Thus, China could be persuaded to reduce its emissions out of a desire to keep its cities livable and its maintain strong relations with the European Union, who thus far have been the greatest champions of stricter emissions standards.

[161] UN, 2014.
[162] The Atlantic, 2013.

In general, governments should pursue policies that make the social cost of road transportation more directly felt by commuters and actively phase out fuel subsidies. Both OECD and non-member countries should look for opportunities to instead subsidize rail and BRT, as these modes have the potential to reduce congestion and cut emissions across sectors. China's high-speed rail subsidies are a prime example of this, as most routes sell out months in advance due to the popularity of the system. When rail is unfeasible, BRT systems can be used to provide many of the same promising effects. In fact, exciting developments in BRT are occurring outside OECD membership. For example, Bogota, Columbia currently boasts one of the most promising BRT systems among developing countries, if not the world.[163]

BRT projects like the TransMilenio project, which was initiated 10 years ago, are a good example of another policy issue plaguing less carbon intensive development funding. TransMilenio is one of six projects funded by the U.N. CDM established under Article 12 of the KP.[164] Obtaining CDM funding is not easy, however, and city and regional governments are usually required to file substantial paperwork, which includes certified emissions reductions (CERs).[165] Japan has addressed this barrier through its implementation of Joint Crediting Mechanisms, which help offset Japan's emissions targets through investment in green infrastructure projects that are in line with UNFCCC objectives. As BRT and other low carbon projects proliferate in the developing world, it is important to construct sustainable, accessible financing options, such the Joint Crediting Mechanism and protocols developed by the Asian Development Bank to obtain CDM funding for its projects.[166]

Incentives and support should also be provided for the formation of joint ventures between established global vehicle manufacturers and those in emerging markets. A study of Chinese vehicles showed that those produced in cooperation with global auto manufacturers had significantly lower emissions, higher fuel economy, and incorporated the technologies common on vehicles in markets with strict emissions standards.[167] Increasing the number of such joint ventures in emerging markets will accelerate the adoption of pollution reducing transport technologies. Coordination between all levels of government and private businesses will build upon the growing success of efforts to decrease transport sector emissions and ensure that targets for GHG emissions reductions can be achieved.

Though fragmentation among stakeholders may impact the sustainability of ASI strategies over time, the temporal colocation of air quality and fuel and combustion regulations historically could encourage more cohesive global standards, which would aid enforcement.[168] The Bharat III and China IV emissions and particulate standards emulate the effect of the Euro V and VI standards in regulating fuel efficiency, and continuing to encourage the spread of these and similar standards should remain a priority of global and country-level decision makers. The Global Fuel Efficiency Initiative is another tool for inspiring dialogue on global fuel efficiency

[163] Gronewold, 2011.
[164] Gronewold, 2011; UNFCCC, 2009.
[165] Gronewold, 2011.
[166] ADB, 2013.
[167] ICCT, 2010.
[168] Litman, 2013.

standards among vehicle manufacturers and developing countries. To this end, public investment in transport research as well as incentives for investing in low-carbon technologies are important tools to ensure that the future carbon intensity of transport modes is reduced quickly enough to meet global goals like the 2DS. Refer to the table below for examples of recommended ASI strategies applied to the most important emitters in the transport sector and internationally.

SUMMARY OF ASI INTERVENTIONS BY COUNTRY AND GLOBALLY

Country	Avoid	Shift	Improve
United States	• **Local:** Continue to pursue and strengthen TDM in urban planning. • **State:** Follow California's example and integrate smart growth requirements into state-level legislation for greater enforceability. • **National:** Conduct further case studies and evaluation of TDM strategy implementation, and look for ways to prioritize low emissions infrastructure such as rail in budgeting. • Develop LEED-type standards for transportation infrastructure. • Determine ways to limit support for fossil fuel as an energy source by the federal government.	• **Local and State:** Where feasible, divert funding and political attention to investing in BRT and high-speed rail. • **National**: Create plan for national transport hub system that heavily incorporates multi-modal travel, including light rail.	• Continue to implement progressive fuel economy standards for LDVs and set aggressive standards for MDVs and HDVs. • Encourage displacement of fossil fuels with alternatives by mandating proportion of alternatives not specific fuel volumes. • Encourage air and sea transport technology improvements and alternative fuel use, especially for Arctic shipping.
European Union (28)	• **Local:** Continue to pursue smart growth and TDM policies like congestion pricing. • **Among members:** Conduct case studies on cap and trade policies' effect on member nations, model effects if implemented internationally. • **International**: Disseminate information about success in TDM through outreach and development projects.	• Continue to pursue public transport as a primary option in local, intra-state personal travel and freight. • Market successful case studies to still developing economies like China and India looking to emulate the European Union in terms of urban planning. • Look to expand fiscal incentives for EV infrastructure and vehicle purchases.	• Continue policies that incentivize fuel-efficient low-carbon LDV, MDV, and HDV technologies. • Expand electric vehicle charging infrastructure. • Continue to scale up alternative fuel use. • Internalize cost of emissions from international air and sea transport.
China	• **National:** Determine more sustainable and equitable ways to limit demand for LDV travel, such as distance fees. • Explore ways to phase out inefficient fossil fuel subsidies in a non-disruptive manner and set goals. • Set goals to lessen the emissions intensity of transport infrastructure projects. • **State:** Incorporate smart growth planning through Transit Hub. development	• **Local, State, National:** Continue to expand BRT and light-rail infrastructure. • Continue to explore using fiscal incentives like tax breaks to promote the use of EV and alternative fuel technology and plug-in infrastructure.	• Continue to pursue adoption of emissions and fuel efficiency standards. • Encourage partnerships between domestic and international vehicle manufacturers, to accelerate diffusion of clean technology. • Explore use of alternative fuels that can be easily integrated into transport systems.
India	• **National:** Pursue national standards for smart growth and provide institutional support. • Explore ways to phase out inefficient fossil fuel subsidies. • **State:** Build on existing tendencies to avoid road transport through smart growth and less carbon intensive transport infrastructure development projects.	• **Local:** In nationally and internationally funded development projects, utilize current preference for public transport and rail through investment in BRT and light-rail projects. • **National:** Continue to pursue rail as the dominant form of freight, and use the strength of the Black Carbon Initiative and black carbon tax to prevent lorry traffic from	• Continue to pursue adoption of emissions and fuel efficiency standards. • Encourage partnerships between domestic and international vehicle manufacturers, to accelerate diffusion of clean technology. • Explore use of alternative

		absorbing rail's market share of freight.	fuels that can be easily integrated into transport systems.
Global	• Pursue solutions through the IMF and other forums for fossil fuel subsidy phase-out. • Revisit cap and trade policies, and invite all international and regional actors to an appropriate forum. • Invest in creating a standardized set of tools and database for emissions reduction potential for planning-based strategies through increased support to research organizations like WRI. • **International:** Conduct a forum for OECD and non-members to discuss efforts to implement standards regarding international transport emissions and road infrastructure through the ITF and ICCT.	• Aid developing economies in locating funding from light-rail, BRT, and EV infrastructure projects through the offset mechanism of CDM and bilateral investment.	• Pursue agreement on global average fuel economy standard in line with IEA suggestion (4.0 Lge/ 100 km ≅ 59 mpg). • Pursue regional or global agreements regulating international air and sea transport emissions, especially in sensitive areas like the Arctic. • Encourage use of alternative fuels appropriate for country contexts. • Increase prevalence of international vehicle manufacturing partnerships to accelerate diffusion of cleaner technologies.

REFERENCES

APEC Energy Working Group. (2012). "Reforming Fossil‑Fuel Subsidies to Reduce Waste and Limit CO_2 Emissions while Protecting the Poor." APEC Energy Working Group September." APEC/GIS/IISD. Singapore. Retrieved from: http://www.iisd.org/gsi/sites/default/files/ffs_apec.pdf.

Asian Development Bank. (2010). "Reducing Carbon Emissions from Transport Projects." Retrieved from: http://www.adb.org/sites/default/files/EKB-REG-2010-16_0.pdf.

Asian Development Bank. (2013). "The Clean Development Mechanism: A Field Guide for Transport Projects." Retrieved from: http://www.adb.org/documents/clean-development-mechanism-field-guide-transport-projects.

The Atlantic. (2013). "The American Commuter Spends 38 Hours a Week Stuck in Traffic." Retrieved from http://www.theatlantic.com/business/archive/2013/02/the-american-commuter-spends-38-hours-a-year-stuck-in-traffic/272905/.

Boske, Leigh. (2013). "Freight's Role in Reducing Transport-Related Emissions." Key Informant Interview, October 25, 2013.

Boske, Leigh; Gamkhar, Shama; Harrison, Robert. (2013). "Texas Highway Funding Options: TxDOT 0-6802-1. Retrieved from: http://library.ctr.utexas.edu/ctr-publications/0-6802-1.pdf.

Bloomberg News. (2013). "Chinese City Proposes Vehicle Restrictions to Reduce Smog." Retrieved from: http://www.bloomberg.com/news/2013-06-19/capital-of-chinese-province-with-worst-smog-restricts-car-sales.html.

Broaddus, Andrea; Todd Litman & Gopinath Menon (2009). Transportation Demand Management: Training Document: Transportation Policy Advisory Services (GTZ). Retrieved from: http://www.sutp.org/en-dn-td.

Busby, Joshua (2013). "The G-20 and Climate Change: Beyond Goal Setting at Brisbane." Lowy Institute for International Policy. Retrieved from: http://www.lowyinstitute.org/files/busby_the_g20_and_climate_change_-_beyond_goal-setting_at_brisbane.pdf.

CA.gov. (2014). "Low Carbon Fuel Standard Program." Retrieved from: http://www.arb.ca.gov/fuels/lcfs/lcfs-background.htm.

Carbon Recycling International (2012). "First Commercial Plant." Retrieved from: http://www.carbonrecycling.is/index.php?option=com_content&view=article&id=14&Itemid=8&lang=en.

CBC News. (2010). "Developed countries outsource emissions: study." Retrieved from: http://www.cbc.ca/news/technology/developed-countries-outsource-emissions-study-1.969087.

CBS News. (2014). "China Breaks New World Record for Car Sales." Retrieved from: http://www.cbsnews.com/news/china-breaks-world-record-for-car-sales-in-2013/.

Center for New Urbanism. (2011). “Charter of the New Urbanism.” Retrieved from: http://www.cnu.org/charter.

Chicago Metropolitan Agency for Planning. (2013). “Congestion Pricing.” Retrieved from: http://www.cmap.illinois.gov/about/2040/supporting-materials/process-archive/strategy-papers/pricing-and-managed-facilities/congestion-pricing.

Cristea et al. (2011). “Trade and the Greenhouse Gas Emissions from International Freight Transport. “NBER Working Paper No. w17117. Retrieved from: http://ssrn.com/abstract=1861858.

Dolan, Ed. (2013). “Are Cheap Fossil Fuels Really a Such a Boon to the World’s Poor?” Wall Street Cheat Sheet: Energy. Retrieved from: http://wallstcheatsheet.com/stocks/are-cheap-fossil-fuels-really-a-such-a-boon-to-the-worlds-poor.html/?a=viewall.

Dalkmann, Holger. (2011). J Dean. (2008, May 7). “Q&A with Holger Dalkmann: Creating a Vision for Sustainable Cities.” [Web log entry]. Retrieved from: http://www.wri.org/blog/qa-holger-dalkmann-creating-vision-sustainable-cities.

Dalkmann, Holger and Charlotte Brannigan. (2007). “Transport and Climate Change: GTZ Sustainable Urban Transport Sourcebook.” Clean Air Portal. Clean Air Initiative. Retrieved from: http://cleanairinitiative.org/portal/node/2482.

Dalkmann, Holger & Cornie Huizenga (2010). “Advancing Sustainable Low-Carbon Transport through the GEF.” Global Environment Facility. Retrieved from: http://www.thegef.org/gef/sites/thegef.org/files/publication/STAP-Sustainable%20transport.pdf.

Diesel.net (2014). “Global Comparison of the International Council on Clean Transportation: Heavy Duty Emissions.” Retrieved from http://transportpolicy.net/index.php?title=Global_Comparison:_Heavy-duty_Emissions.

The Economic Times. (2013). “Government Targets to Roll Out Subsidies for Electric Cars by April 2014.” Retrieved from: http://articles.economictimes.indiatimes.com/2013-11-28/news/44546813_1_finance-ministry-mahindra-reva-incentive.

Edmunds Car Sales. (2013). Retrieved from: edmunds.com.

EMBARQ/WRI. (2014). “Global BRT Data.” http://www.brtdata.org/#/location.

EPA/Office of Transportation and Air Quality. (2014). “Fuel Economy: Regulations and Standards.” Retrieved from: http://www.epa.gov/fueleconomy/regulations.htm.

EU Climate Action. (2013). “What is the EU Doing About Climate Change?” Retrieved from: http://ec.europa.eu/clima/policies/brief/eu/index_en.htm.

EU Environment. (2014). “Transport & Environment.” Retrieved from: http://ec.europa.eu/environment/air/transport/.

Façanha, Cristiano; Kate Blumberg & Josh Miller. (2012). "Global Transportation: Energy and Climate Roadmap." International Council for Clean Transportation. Retrieved from: http://www.theicct.org/sites/default/files/publications/ICCT%20Roadmap%20Energy%20Report.pdf.

Farzaneh, Reza; Kristen Novak; Richard Baker & Ginger Goodin. (2012, March). "Use of Performance Measurement to Include Air Quality and Energy into Mileage-Based User Fees."(2012). University Transportation Center for Mobility. Retrieved from: http://utcm.tamu.edu/publications/final_reports/Farzaneh_10-25-50.pdf.

Frease, McKenna. (2012). "The Arctic, maritime shipping, and black carbon,"

The International Council on Clean Transportation. Retrieved from: http://www.theicct.org/blogs/staff/edit-blog-post-arctic-maritime-shipping-and-black-carbon.

Fuel Economy.com. (2014). "Fuel Efficient Vehicle Tax Incentive Information Center." Retrieved from: http://www.fueleconomy.gov/feg/taxevb.shtml.

GN Transport. (2013). "MAUT – German Road Tax." Retrieved from: http://www.gntransport.se/en/Maut.asp.

Harmel, P. (1970). "Transport and the Environment: Road Vehicles." Directive 70/220/EEC. Office Journal of the European Communities. Retrieved from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=DD:I:1970_I:31970L0220:EN:PDF.

International Transport Forum. (2010). "Reducing Transport Greenhouse Gas Emissions:Trends and Data 2010," Retrieved from: http://www.internationaltransportforum.org/Pub/pdf/10GHGTrends.pdf.

The International Council on Clean Transportation. (2012). "Emissions Reductions Strategies and Technologies." Retrieved from: www.theicct.org/sites/default/.../ICCT_Emissions_Control_Strategies.xlsx.

The International Council on Clean Transportation (2014). "India." Retrieved from http://www.theicct.org/countryregion/asia/india.

International Maritime Organization. (2013). "Greenhouse Gas Emissions." Retrieved from: http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx.

Joint Research Center: Emissions Database for Global Atmospheric Research. (2013, December 17). Retrieved from: http://edgar.jrc.ec.europa.eu/methodology.php#.

Litman, Todd. (2013). "Understanding Transport Demands and Elasticities: How Policies and Other Factors Affect Travel Behavior." Retrieved from: http://www.vtpi.org/elasticities.pdf.

McKinsey, Climate Desk (2009). Retrieved from: http://solutions.mckinsey.com/climatedesk.

Metropolitan Planning Council. (2014). "The Connector: BRT Case Study: Cleveland, Ohio." Retrieved from: http://www.metroplanning.org/news-events/blog-post/6203.

OECD.org. (2013). "China and the OECD." Retrieved from: http://www.oecd.org/china/.

OECD/IEA. (2013). "A Tale of Renewed Cities: A policy guide on how to transform cities by improving energy efficiency in urban transport systems." Paris. Retrieved from: http://www.iea.org/publications/freepublications/publication/name,39940,en.html.

OECD/IEA. (2011). "Energy Technologies Perspectives 2011a.

OECD/IEA. (2012). "Energy Technologies Perspectives 2012." Paris. 423-456.

OECD/IEA. (2013). "Global Land Transport Infrastructure Requirements: Estimating road and railway infrastructure capacity and costs to 2050." 2013. Paris. Retrieved from: http://www.iea.org/publications/freepublications/publication/TransportInfrastructureInsights_FINAL_WEB.pdf.

OECD/ITF. (2009). "The Cost and Efficiency of Reducing Transport GHG Emissions: Preliminary Findings." Paris: 18.

Partnership on Sustainable Low Carbon Transport (SLoCat). (2013). "Work Program 2013-2014." Retrieved from: http://www.slocat.net/sites/default/files/updated_slocat_work_program_-_2013-2014_january_2014.pdf.

Peters, Joey. (2011). "Could Carbon Labeling Combat Climate Change?" Climate Wire. Retrieved from: http://www.scientificamerican.com/article.cfm?id=could-carbon-labeling-combat-climate-change.

Robert Perkins. (2013). "Olah and Prakash receive $1 million award for Innovative fuel research." USC News. Retrieved from: http://news.usc.edu/#!/article/56392/olah-and-prakash-receive-1-million-award-for-innovative-fuel-research/

Roeth et al. (2013). "Barriers to the Increased Adoption of Fuel Efficiency Technologies in the North American On-Road Freight Sector," International Council for Clean Transportation. Retrieved from: http://www.theicct.org/sites/default/files/publications/ICCT-NACFE-CSS_Barriers_Report_Final_20130722.pdf.

Regulation (EC) No 582/2011. (May 25, 2011). Official Journal of the European Union. Retrieved from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:167:0001:0168:EN:PDF.

Renewable Fuels Association. (2013). "Fossil Fuel Subsidies Reach $544 Billion as Another UN Climate Change Conference Ends." Retrieved from: http://www.ethanolrfa.org/news/entry/fossil-fuel-subsidies-reach-544-billion-as-another-un-climate-change-confer/.

Robinson, Ferrol & David Coyle. (2011). "Can the Trucking Industry Benefit from Distance-Based Fees?" University of Minnesota. 22nd Annual Transportation Research Conference, Center for Transportation Studies. Presentation. Retrieved from: http://www.cts.umn.edu/events/conference/2011/documents/presentations/3-robinson-o.pdf.

Rosenthal, Elisabeth. (2013). "The End of Car Culture." The New York Times. Retrieved from: http://www.nytimes.com/2013/06/30/sunday-review/the-end-of-car-culture.html?_r=1&.

Sakamoto, et al. (2010). "A Paradigm Shift towards Sustainable Low-Carbon Transport." Institute for Transportation and Development Policy. Retrieved from: http://www.itdp.org/documents/A_Paradigm_Shift_toward_Sustainable_Transport.pdf.

Seas at Risk. (2010). "Going Slow to Reduce Emissions: Can the current surplus of maritime transport capacity be turned into an opportunity to reduce GHG emissions." Retrieved from: http://www.seas-at-risk.org/pdfs/speed%20study_Final%20version_SS.pdf.

Short, John R. (2013). "Liquid City: Megalopolis and the Contemporary Northeast." Washington, DC: Resources for the Future. 23.

Silverspring.net. (2014). "Taking Charge of EVs." Retrieved from: http://www.silverspringnet.com/solutions/electric-vehicles/#.Uvdwfvl1xRY.

Strompen, Frederik ; Todd Litman & Daniel Brongardt. (2012). "Reducing Carbon Emissions through Transport Demand Management Strategies: A review of international examples." GIZ/TRC. Retrieved from: http://tdm-beijing.org/files/International_Review.pdf.

Teslamotors.com. (2014). "Electric Vehicle Incentives Around the World." Retrieved from: http://www.teslamotors.com/incentives/US.

Transportation for London. (2007). "Central London Congestion Charging: Impacts Monitoring." Fifth Annual Report. Retrieved from: http://www.tfl.gov.uk/assets/downloads/fifth-annual-impacts-monitoring-report-2007-07-07.pdf.

UNCSD/ SLoCAT (2012). "Rio 2012 Issues Briefs: Sustainable Low Carbon Transport in Emerging and Developing Economies." Retrieved from: http://sustainabledevelopment.un.org/content/documents/403brief13.pdf.

United Nations Conference on Environment and Development. (1992). "Briefing Notes." Retrieved from: http://www.un.org/geninfo/bp/enviro.html.

United Nations Framework Convention on Climate Change, Third Session. (2007, December). "Emissions from fuel used for international aviation and maritime transport (international bunker fuels)." Retrieved from: http://unfccc.int/methods/emissions_from_intl_transport/items/1057.php.

United Nations Framework Convention on Climate Change. (2009). "Copenhagen Accord, 15th Conference of Parties." Draft Decision –CP.15. Retrieved from: http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf.

UNFCCC.org. (2014). "Kyoto Protocol." Retrieved from: https://unfccc.int/kyoto_protocol/items/2830.php.

United Nations Department of Economic and Social Affairs. (2014). "Low Carbon Development." Retrieved from: http://sustainabledevelopment.un.org/index.php?menu=1448.

U.S. Census Bureau. (2013). "Geographically Updated Population Certification Program." Retrieved from: http://www.census.gov/geo/reference/frn.html.

U.S. Department of Transportation. (2014). "Highway Trust Fund Ticker." Retrieved from: http://www.dot.gov/highway-trust-fund-ticker.

U.S. Environmental Protection Agency. (2013). "EPA Proposes 2014 Renewable Fuel Standards / Proposal Seeks Input to Address E10 Blend Wall, Reaffirms Commitment to Biofuels." Retrieved from: http://yosemite.epa.gov/opa/admpress.nsf/6424ac1caa800aab85257359003f5337/81c99e6d27c730c485257c24005eecb0!OpenDocument.

U.S. Environmental Protection Agency. (2014). "Global Greenhouse Emissions Data." Retrieved from: http://www.epa.gov/climatechange/ghgemissions/global.html.

U.S. National Highway Transportation Safety Administration. (2012, August 28). "Obama Administration Finalizes Historic 54.5 mpg Fuel Efficiency Standards." Retrieved from: http://www.nhtsa.gov/About+NHTSA/Press+Releases/2012/Obama+Administration+Finalizes+Historic+54.5+mpg+Fuel+Efficiency+Standards.

Victoria Transport Policy Institute. (2013). Online TDM Encyclopedia. Retrieved from: http://www.vtpi.org/tdm/.

World Bank. (2014). "Road Financing and Road Funds." Retrieved from: http://www.worldbank.org/transport/roads/rd_fnds.htm.

World Health Organization. (2013). "World Health Statistics 2013." Retrieved from: http://www.who.int/gho/publications/world_health_statistics/2013/en/.

World Resources Institute. Cait 2.0: Climate Data Explorer. Retrieved from: http://cait2.wri.org/.