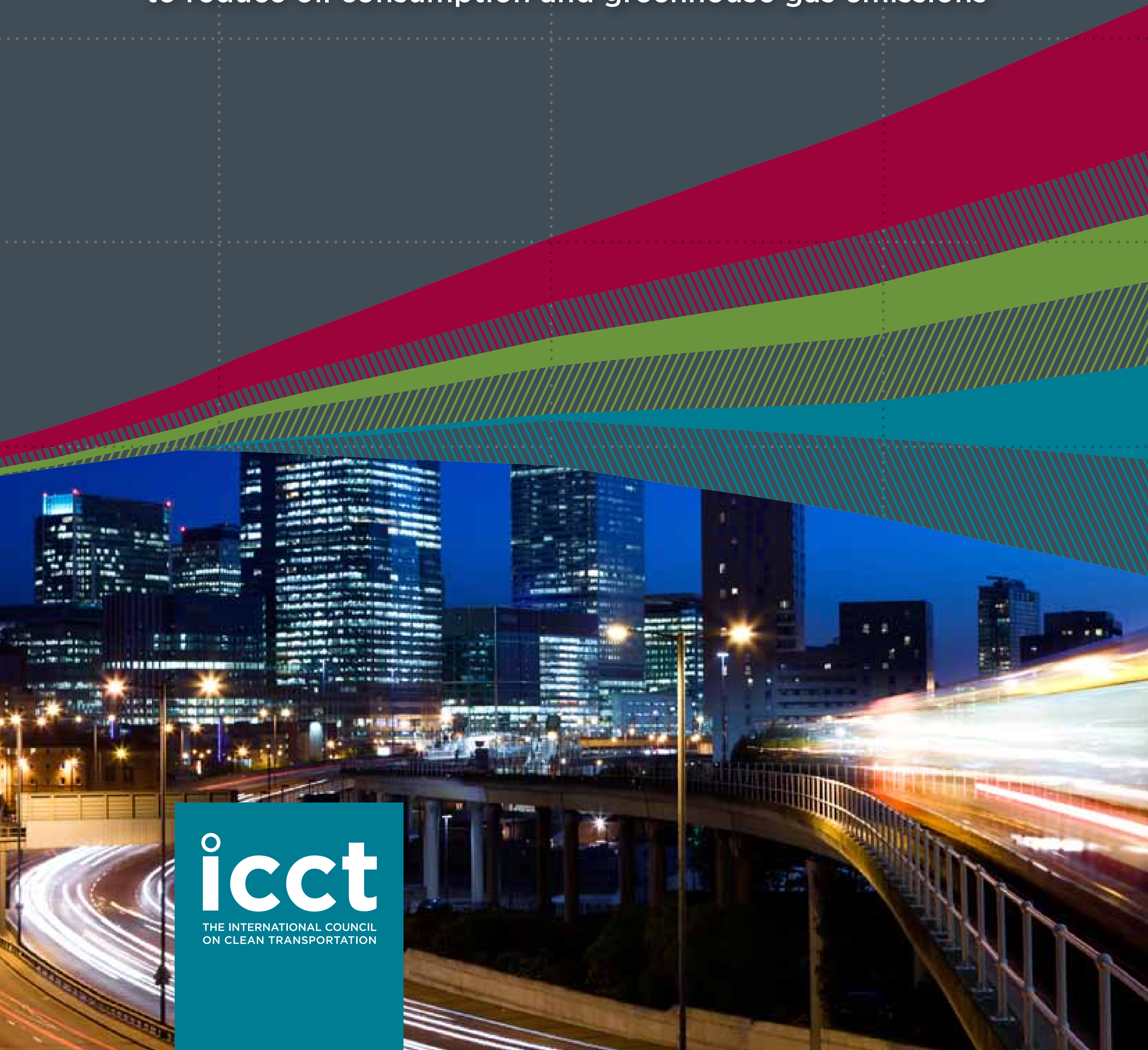
Global Transportation Energy and Climate ROADMAP

The impact of transportation policies and their potential to reduce oil consumption and greenhouse gas emissions



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The International Council on Clean Transportation is an independent nonprofit organization founded to provide high-quality research and analysis to governments in the world's major vehicle markets. Our mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation in order to benefit public health and mitigate climate change. For more information on our Global Roadmap, please visit www.theicct.org.

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This report is dedicated to the memory of Dr. Lee Schipper (April 7, 1947 – August 16, 2011). We keenly missed Lee's insights and critical review for this analysis, as we miss his intelligence, warmth, and humor throughout our work and lives.

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EXECUTIVE SUMMARY

This report evaluates the impact of transportation policies on worldwide oil consumption and greenhouse gas (GHG) emissions and the potential for the reduction of both out to 2030. Its analysis finds that policies adopted and formally announced since 2000 will dramatically reduce oil consumption and GHG emissions from the transportation sector. Specifically, these policies will slow the growth of global oil consumption and GHG emissions and will result in a reduction of 14 percent in global oil consumption and 7 percent in global economy-wide GHG emissions below 2030 levels in the International Energy Agency (IEA)'s World Energy Outlook.[1] The analysis concludes that spreading the world's most advanced regulatory standards and cost-effective technologies to other major markets while supporting shifts to low-carbon modes could more than double these impressive reductions, essentially stabilizing global transportation emissions by 2020. Despite the large magnitude of emission reductions that can be achieved from the adoption and implementation of transportation policies, these policies will not put the transportation sector on a trajectory to reduce emissions by 50 to 85 percent by 2050 from 2000 levels, which is the extent of economy-wide emission reductions agreed upon by governments worldwide as necessary to constrain temperature increases to two degrees Celsius.[2] Such reductions from the transportation sector would require the adoption of a wider range of policies, along with a transformation of vehicle technologies and transportation systems, to increase the annual rate of emission reductions in the 2030 to 2050 time frame and meet the 50–85 percent target.

Transportation currently accounts for about half of global oil consumption and one-quarter of global GHG emissions from fossil fuels; moreover, transportation-driven carbon dioxide (CO_2) emissions have increased more rapidly than total global emissions in the past two decades.[3] The transportation sector—including passenger vehicles, commercial trucks, rail, marine, and aviation—is expected to continue to grow at a similar pace over the next decade. In line with current trends, our model baseline predicts a doubling of the world's motor vehicle population over the next twenty years, which is similar to other expert predictions,[4] with comparable growth rates projected for the overall transportation sector. These forecasts underscore the importance of current and future policies that target reductions in oil consumption and GHGs from the transportation sector.

After the first passenger vehicle efficiency standards made impressive gains in U.S. efficiency in the 1970s, regulatory standards stalled, and reductions of CO_2 emissions and fuel consumption lagged for several decades. A recent resurgence in fuel efficiency and CO_2 standards has started to change this course. Recently adopted or proposed regulations in the United States, Europe, Japan, and China with standards out to 2020 or 2025 are driving technology development that will reduce average new passenger vehicle CO_2 emission rates by 19 to 50 percent below 2010 levels. The reductions achieved by these standards, however, will not offset global emissions growth in the sector, much of which is being driven by rapid expansion in vehicle fleets and activity in developing countries. Activity and mode share trends worldwide still indicate an increasing reliance on private automobiles and aviation, and the trucking sector continues to dominate goods movement in most regions, with the exception of bulk commodities. In order to respond fully to the daunting challenges of climate change and oil dependence, the transportation sector will require continued incremental improvements and eventually fundamental shifts in technology, along with changes in how people and freight move.

Over the course of the past decade, a number of reports and modeling exercises have been published about the technology pathways necessary to achieve major reductions in GHG emissions. This work has provided much valuable information and analysis, highlighting the central fact that there is no single technology or policy answer.[5, 6, 7, 8, 9, 10] Most of these studies have focused primarily on long-term targets and the available technology options that could achieve such targets, without consideration of the policy pathways necessary to reach such a technology mix. As a result, none of these studies has given regulators and policymakers a clear understanding of the policy options, which they need most immediately. ICCT's Roadmap offers a global view of the transportation sector. This analysis is supported by a publicly available, transparent model that provides a quantitative means of understanding the benefits of past policies and emission reduction potential of future government action.

This report seeks to provide government regulators, policymakers, and other stakeholders with answers to some critical policy questions:

- What is the current growth rate in energy and GHG emissions from the transportation sector by mode and region?
- What are the energy and emission benefits of past and existing transportation policies?
- What is the potential to reduce further energy consumption and GHG emissions from the transportation sector?
- How do countries compare in terms of vehicle efficiency and mode shares?

To answer these questions, the ICCT developed the Global Transportation Roadmap model, an analytical tool that draws upon the best available data for global and national transportation emissions and policies. The Roadmap model focuses on the top vehicle markets, which are the largest GHG emitters and oil consumers within the transportation sector. These also tend to develop and adopt emission control and energy efficiency regulations first. Their experience establishes a suite of best-practice policies to draw upon.

GLOBAL TRANSPORTATION ROADMAP MODEL

OUTPUTS

- Energy and oil consumption
- GHG emissions (CO_2, CH_4, N_2O, BC)
- Local pollutants (PM, NO_x, HC, CO, SO_2

MODES

- On-road passenger vehicles
- On-road commercial trucks
- Passenger and freight locomotives
- Passenger aircraft
- Freight marine vessels

REGIONS

- United States
- EU-27
- China
- India
- Japan
- Brazil
- Canada
- South Korea
- Mexico
- Australia

Global results also include:

- Russia
- Rest of Latin America
- Rest of Asia-Pacific
- Rest of Europe
- Africa
- Middle East

The ICCT collaborated closely with government agencies and experts from each of the regions highlighted in this report to ensure that the model includes the most representative and credible publicly available data. The ICCT also collaborated extensively with the Institute for Transportation and Development Policy (ITDP) on the analysis of mode shift and activity reduction policies, as well as the IEA through the Mobility Model (MoMo) partnership on data collection and emissions modeling.

ANALYTICAL FRAMEWORK

This report quantifies oil consumption and GHG reduction from government policies adopted or formally announced since 2000 and the potential benefits of expanding world-class regulatory programs, cost-effective technologies, and infrastructure investments in low-carbon modes to all major markets. This analysis focuses on near-term regulatory time frames in order to inform upcoming policymaking efforts. As such, it is based on the deployment of vehicle technologies currently being commercialized and avoids speculative assumptions about dramatic transformations in the transportation sector. Therefore, the analysis is limited to the 2030 time horizon. Emission reductions from near-term policies are estimated relative to a reference trajectory, in which future mode shares and activity growth are consistent with historical and socioeconomic trends. For each principal region and globally, policies are grouped into three trajectories:

> **ADOPTED** Includes all existing, enforceable, and finalized regulations published in official government publications and adopted from 2000 to present but assumes no autonomous changes in vehicle efficiency for modes other than aviation or further penetration of electric-drive vehicles or lower-carbon fuels.
>
> **PIPELINE** Includes formally announced or proposed regulations, by a government agency with relevant regulatory authority, with sufficient specificity to estimate potential benefits (e.g., quantitative target and timeline). Policies in the pipeline include vehicle efficiency and/or GHG standards for passenger vehicles, heavy-duty trucks, aircraft, and marine vessels; market-based measures for aircraft and marine vessels; as well as fully and partially funded projects to increase public transit infrastructure.
>
> **POTENTIAL** Includes a more complete range of best-practice vehicle efficiency, mode shift, and activity (demand for travel or shipping) reduction strategies that are feasible from a technical and operational perspective out to 2030, resulting in a trajectory that is ambitious but achievable. This analysis does not consider political willingness to implement these policies and strategies but includes a reasonable time lag for policy development and adoption, as well as infrastructure development. For those countries with specific policies in place or under way, additional potential is calculated to 2030 only beginning after the close of the current regulatory time frame. In addition to improved vehicle efficiency, this trajectory includes shifts from passenger vehicles to mass transit and nonmotorized modes, as well as shifts from long-distance trucking to freight rail. Complementary policies to reduce the average length of urban trips and to improve logistics operations are also considered. While additional reductions could likely be achieved through more comprehensive logistics improvements and a widespread application of information,

communication, and pricing technologies to manage transportation supply and demand, these measures were not assessed in the analysis.

For all three trajectories, efficiency for the marine and aviation sectors is considered at the global level.

GLOBAL TRANSPORTATION HEALTH AND CLIMATE ROADMAP

The ICCT is currently using the Roadmap model to develop a separate analysis of health impacts from transportation, focusing on local air pollutants such as particulate matter, nitrogen oxides, hydrocarbons, and carbon monoxide, and the impacts of what are termed "short-lived climate forcers," primarily black carbon.

Reductions in emissions of local air pollutants from the transportation sector over the past several decades have shown how effective transportation regulations can be. Government regulations have been responsible for driving the development of emission control technologies for passenger vehicles and heavy-duty trucks that are capable of reducing emissions of local air pollutants by more than 90 percent, assuming test cycle conditions. Europe, Japan, and the United States play a leadership role in developing world-class conventional pollutant emission standards, with other nations adopting either European or U.S. regulatory standards and technologies. Transfer of pioneering policies and technologies to developing nations lags largely because of poor-quality fuels, although limited resources to implement strong compliance and enforcement procedures and the absence of enforceable targets for health-based ambient air quality standards also play a role. In addition, developing nations often lack information about the types and costs of available technologies that are needed to comply with world-class standards.

This second Roadmap report will highlight policy options that are available to reduce local air pollutants and will quantify the reductions in mortality that can be achieved through these interventions. It will also highlight the important climate co-benefits from these policies, primarily attributable to black carbon reduction. The traditional lines between local air pollutants and the Kyoto Protocol basket of GHGs are blurring as a growing body of scientific evidence demonstrates a substantial contribution to climate change from ground-level ozone and black carbon (an important component of particulate matter emissions from vehicles). The ICCT recognizes that climate change and local air pollution are closely linked and recommends that programs to reduce emissions in both categories should be designed in parallel. However, because the base sets of technologies and policies targeting GHG emissions[a] are very different from those targeting local air pollutants and each face a different array of obstacles, the ICCT chose to separate the analyses in order to give the proper level of attention and focus to the policies and benefits relevant to each class of pollutants.

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[a] This analysis considers carbon dioxide, methane, and nitrogen oxide in the calculation of CO_2-equivalent using a global warming potential on a 100-year time scale taken from the IPCC 4th Assessment report.

Table 1 provides an overview of adopted, pipeline, and potential policies considered for each region. Policies are categorized according to an A-S-I-T (Avoid-Shift-Improve-Transform) framework described in Chapter 1. Policies to *improve* vehicle efficiency and *transform* the vehicle fleet to zero-emission technologies include vehicle fuel efficiency or GHG standards, fiscal incentives, and low-carbon fuels, as well as incentives for zero-tailpipe-emission vehicles and refueling infrastructure. Policies to *shift* transportation activity from private automobiles and long-distance trucking to mass transit, nonmotorized transportation, and freight rail, and to *avoid* transportation activity, include mass transit and freight rail infrastructure investments, travel demand management strategies, land-use policies, fiscal measures, and market-based measures to reduce marine and aviation activity. Although fiscal measures are an important complement to many of the policies included here (e.g., vehicle efficiency standards, public transit investments), this analysis does not quantify the explicit effects of such price signals on transportation activity and emissions. The complete set of policy assumptions is described in the main body of the report.

TABLE 1. Summary of Policies Analyzed

Region / Mode	Improve			Transform	Shift*	Avoid
	LDV	HDV	Other			
United States	🔴🔵	🔴🔵		🔴🔵	🟢🔵	🔵
EU-27	🔴🟢🔵	🔴🔵		🔵	🟢🔵	🔴🔵
China	🔴🟢🔵	🔴🟢🔵		🔵	🟢🔵	🔵
India	🟢🔵	🔵		🔵	🟢🔵	🔵
Japan	🔴🔵	🔴🔵		🔵	🟢🔵	🔵
Brazil	🔴🟢🔵	🔵	🔴🟢‡	🔵	🟢🔵	🔵
Canada	🔴🟢🔵	🟢🔵		🔵	🟢🔵	🔵
South Korea	🔴🔵	🔵		🔵	🟢🔵	🔵
Mexico	🟢🔵	🟢🔵		🔵	🟢🔵	🔵
Australia	🟢🔵	🔵		🔵	🟢🔵	🔵
Marine			🔴🟢🔵			🟢🔵
Aviation			🟢🔵			🔴🟢🔵

🔴 Adopted 🟢 Pipeline 🔵 Potential ‡Fuels *Adopted mode-shift policies included in *Pipeline* trajectory.

REPORT HIGHLIGHTS

The central purpose of this analysis is to quantify the benefits over the past decade and out to 2030 of government policies on transportation-related oil consumption and GHG emissions. These reductions must be appreciated within the context of substantial growth in global transportation activity. Between 2000 and 2030, it is forecast that transportation activity will more than double in most modes, and as a result oil use and GHG emissions are also projected to double in the reference trajectory. Significantly, this analysis focuses on the top ten major vehicle markets that accounted for more than 78 percent of new light-duty vehicle (LDV) and heavy-duty truck sales in 2010 (see Global Transportation Roadmap Model text box for a list of these markets). Major findings follow:

- Policies adopted since 2000 in major vehicle markets will reduce global oil-equivalent consumption by 9.7 million barrels per day (Mboe/day) and GHG emissions by 1.9 metric gigatons of CO_2 equivalent ($GtCO_2e$) in 2030 (Figure 1).[b] These reductions will be equivalent to 9 percent of global oil consumption and 4 percent of global all-sector GHG emissions from 2030 levels in IEA's World Energy Outlook.

- If adopted according to current expectations, policies in the pipeline will further increase these benefits. Together, adopted and pipeline policies represent reductions of 14.5 Mboe/day and 2.9 $GtCO_2e$ in 2030, equivalent to a 14 percent reduction in global oil consumption and a 7 percent reduction in global economy-wide GHG emissions from 2030 levels in IEA's World Energy Outlook. Policies to improve the efficiency of on-road vehicles, marine vessels, and aircraft will accomplish the lion's share of reductions.
- The full benefits of concerted regulatory action and rapid penetration of cost-effective technologies are illustrated by LDV policies. Despite a doubling of projected vehicle stock from 2000 to 2030, from 640 million to 1.5 billion, oil consumption and GHG emissions from LDVs are projected to stabilize in 2025 thanks to the adoption of strong fuel efficiency and GHG emission standards in major markets since 2005.
- Expansion of world-class policies and cost-effective technologies across the globe—including vehicle efficiency, mode shift, and activity reduction policies—would result in oil and emission reductions of 28.6 Mboe/day and 5.8 $GtCO_2e$ in 2030, equivalent to a 28 percent drop in global oil consumption and a 13 percent cut in global economy-wide GHG emissions from 2030 levels in IEA's World Energy Outlook. This level of reduction would essentially stabilize transportation emissions by the year 2020.

INCREASED POLICY PROGRESS BEYOND 2030, COUPLED WITH A TRANSFORMATION OF THE TRANSPORTATION SECTOR WITH NEW TECHNOLOGIES AND DRAMATIC SHIFTS IN HOW PEOPLE AND FREIGHT MOVE, WILL BE REQUIRED TO CONSTRAIN TEMPERATURE INCREASES TO 2 DEGREE CELSIUS.

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[b] Oil-equivalent reductions are equal to the ratio between total energy saved (calculated based on the energy content of different fuel types) and the energy content of a barrel of oil. Because not 100 percent of fuels are fossil fuels, total oil reductions will be less than total oil-equivalent reductions. Throughout the rest of the report, the term "oil reductions" has the same meaning as "oil-equivalent reductions."

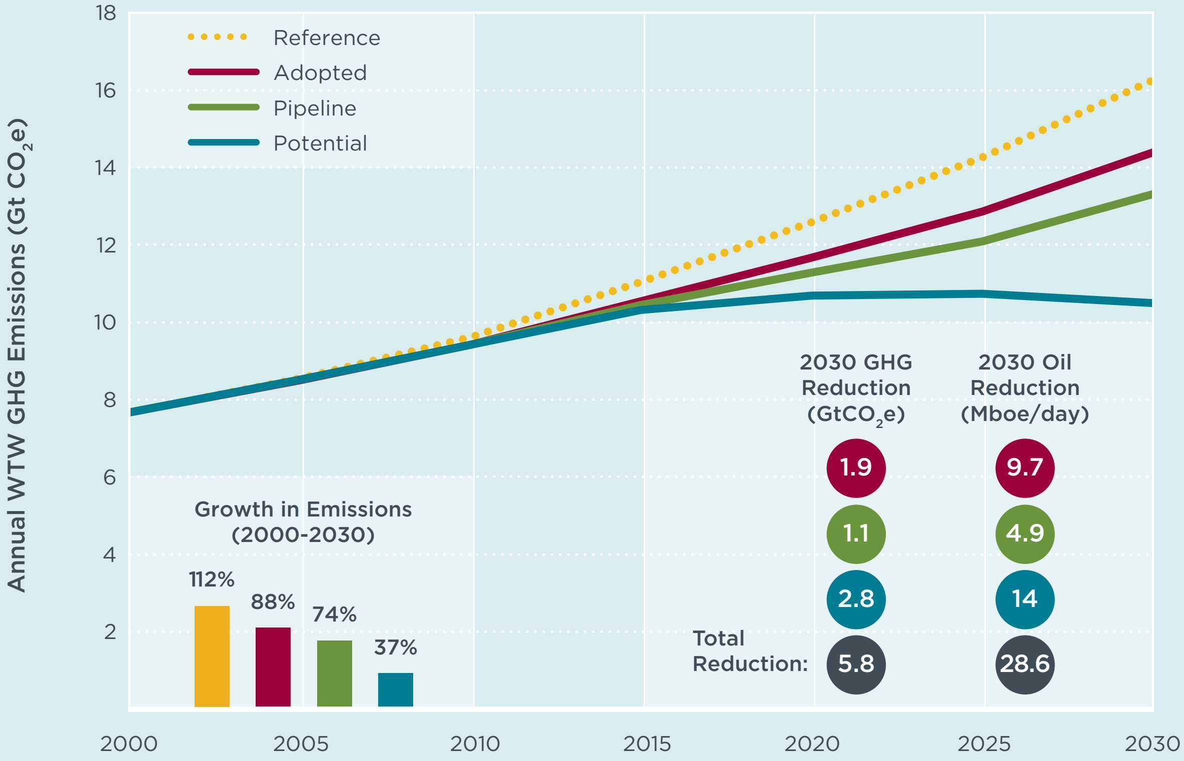

FIGURE 1. Global Transportation Emission Trajectories

In order to limit temperature increases to two degrees Celsius as agreed upon as the global climate change mitigation goal in the 2009 Copenhagen Accord, the Intergovernmental Panel on Climate Change (IPCC) has indicated that global economy-wide GHG emissions must be reduced by 50 to 85 percent from 2000 levels by the year 2050.[11] If activity growth trends continue as predicted following historical trends, global GHG emissions from the transportation sector will increase substantially from 2000 to 2030, despite the large magnitude of reductions from adopted policies. By adding policies in the pipeline, whose implementation is not certain, as well as aggressive potential policies, global transportation GHG emissions could stabilize in 2030 at a level about 37 percent higher than 2000 emissions. Intensified policy progress, coupled with a transformation of the transportation sector with new technologies and dramatic shifts in how people and freight move, will be required to accelerate the rates of emission reduction in the transportation sector if the 50–85 percent target is to be met by 2050.

The following sections discuss the policy landscape for each mode of transportation, as well as the policies analyzed to temper growth in vehicle activity and shift vehicle activity to more energy-efficient modes.

LIGHT-DUTY VEHICLE EFFICIENCY

Light-duty vehicles (LDVs), which include passenger vehicles such as cars, minivans, and sport utility vehicles (SUVs) as well as light commercial vehicles (LCVs), have the strongest track record for regulatory policy. In the United States, after a successful initial response to the global oil crisis of the 1970s, energy regulations for vehicles stagnated for many years, and fleet-average efficiency levels stayed relatively steady as improved technology was used to offset increases in vehicle weight and power. Higher fuel taxes and fiscal incentives in regions like Europe and Japan have limited increases in average size, power, and weight of vehicles, resulting in improved efficiency even in the absence of stringent standards. It is only in the past decade, and especially in the past five years, that the largest vehicle markets (United States, EU-27, China, Japan, Canada, and South Korea) have resumed ambitious, mandatory fuel efficiency and GHG standards for LDVs.

Currently, mandatory fuel efficiency and GHG standards for LDVs are in effect for more than 70 percent of the global new-vehicle market. These standards drive the development and introduction of new energy-efficient technologies, smaller engines, lighter vehicles, and improved aerodynamics and tires. Figure 2 shows the expected new LDV GHG emission rates in the main vehicle markets that have either adopted (solid lines) or formally proposed (dashed lines) fuel efficiency and/or GHG standards.[c]

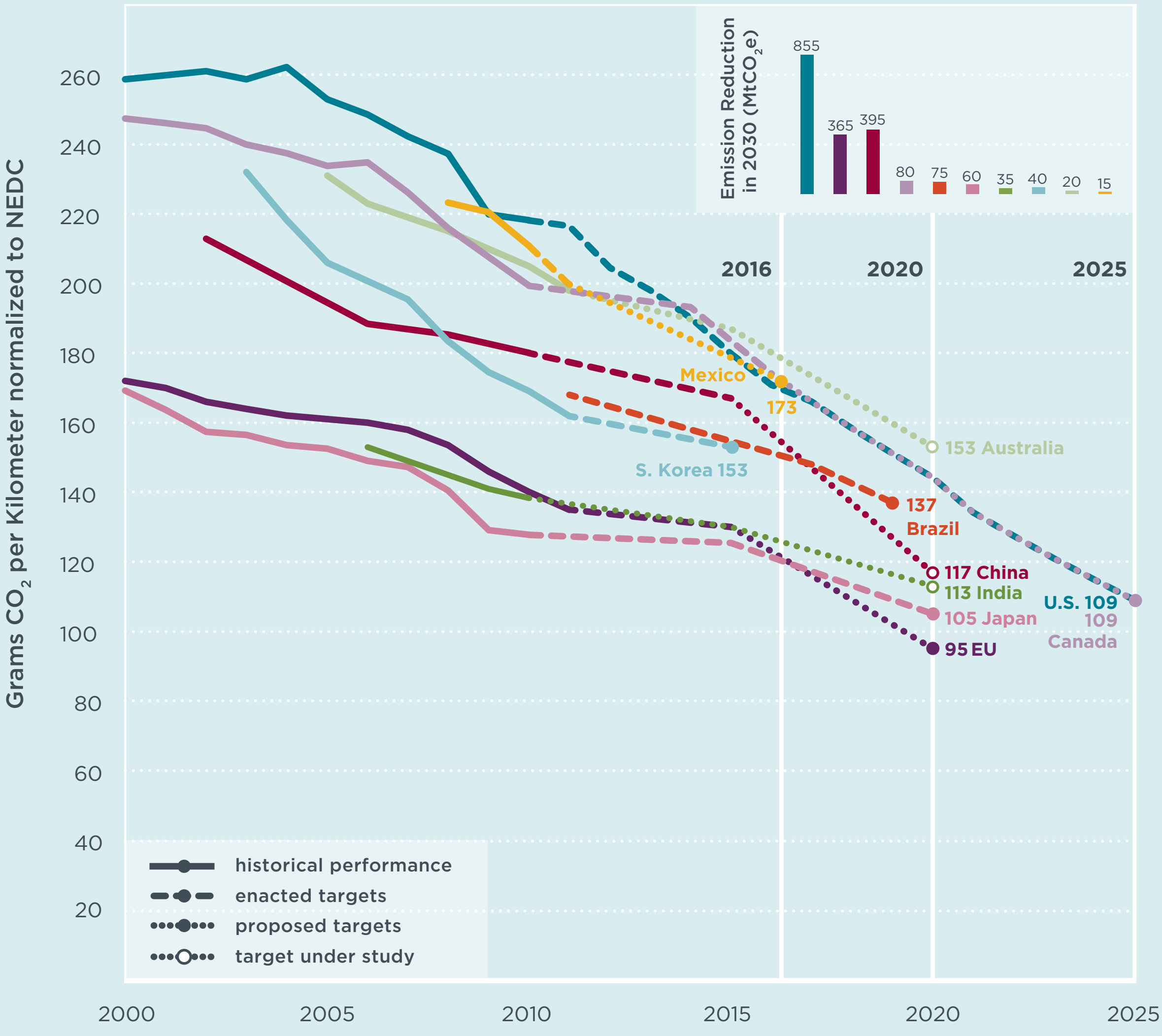

FIGURE 2. Comparison of LDV CO_2 Emission Rates

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[c] Brazil has not yet adopted fuel efficiency or GHG standards for LDVs, but it has recently adopted fiscal measures that take vehicle efficiency into account and will likely achieve effects similar to those of a standard.

While Japan and Europe currently lead the world in terms of new and fleet-average fuel efficiency of passenger vehicles, the United States is expected to achieve the greatest improvement in fuel consumption for new vehicles—a 50 percent reduction from 2000 to 2025. Because of the sheer size of its projected fleet and the fact that it starts from an inefficient baseline, the absolute reduction in emissions from the U.S. standards is expected to exceed 850 million metric tons of CO_2 equivalent ($MtCO_2e$) in 2030, assuming best practices with respect to enforcement and compliance and that the size mix of vehicles sold remains constant. The adopted and pipeline efficiency standards in China and the EU-27 are also expected to generate substantial reductions in 2030—between 360 and 400 $MtCO_2e$ each—along with roughly 45 percent reductions in the fuel consumption of new vehicles between 2000 and 2025. Standards in other countries will not generate comparable emission reductions because of smaller fleet sizes and more modest efficiency improvements (aside from Canada, which has announced its intention to continue harmonization with U.S. standards).

Together, adopted and pipeline fuel efficiency standards for the new light-duty fleet are expected to generate annual reductions of 9.8 Mboe/day and 2 $GtCO_2e$ in 2030. These account for about one-third of total expected reductions from the transportation sector. Without these standards, LDV CO_2 emissions and oil consumption could have almost doubled between 2000 and 2030, with the fastest growth rates occurring in major new markets such as China, India, and Brazil. In essence, the continued improvement of fuel efficiency is required to offset the expected growth in passenger vehicle fleets and activity around the world.

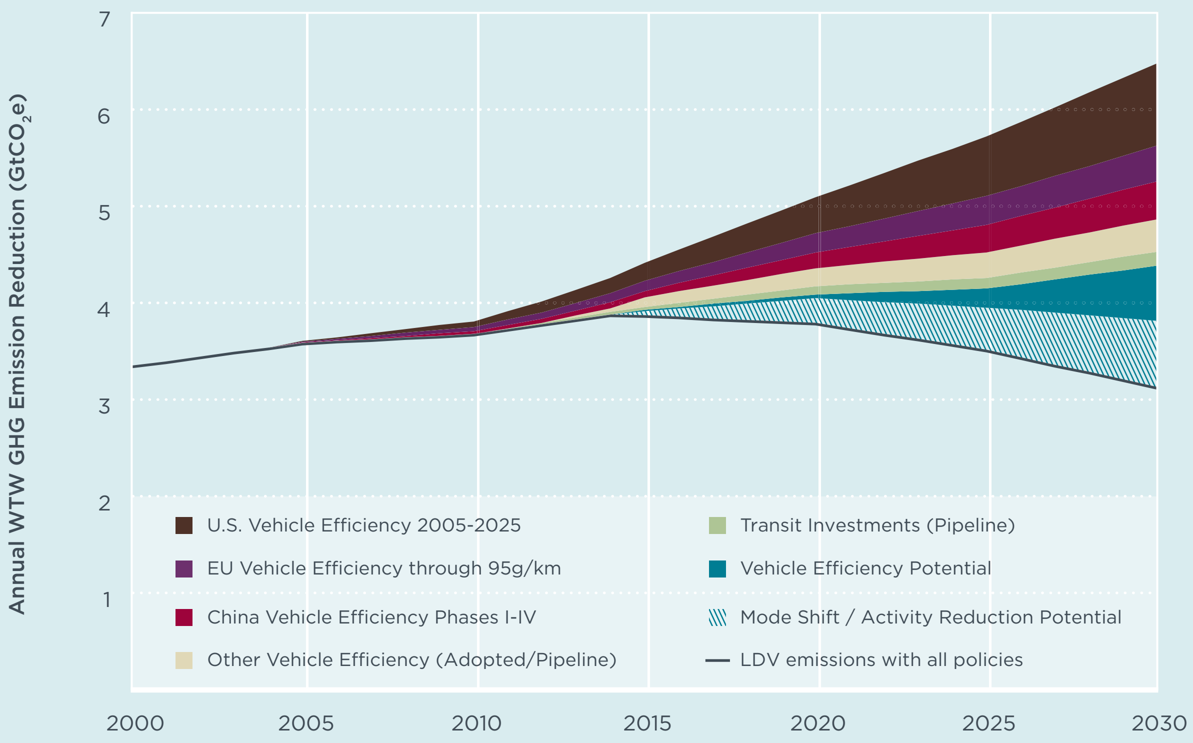

FIGURE 3. Policy Impacts on Global LDV Emissions

Quantifying the potential to reduce oil consumption and GHG emissions out to 2030 entails taking the annual rate of improvement in LDV efficiency achieved under best-practice policies in the United States, Europe, and China, extending it beyond current timelines and planned regulations, and applying this rate of improvement to other regions that currently lack LDV standards. In recognition of the typical policymaking timeline, potential policies to improve vehicle efficiency come into force no sooner than 2015 for the regions highlighted in this report and 2020 for the other regions considered, leaving a somewhat limited time window for policies applied to the new vehicle fleet to be developed and approved. If implemented in addition to existing and upcoming regulations, potential vehicle efficiency improvements could stabilize oil consumption and CO_2 emissions from the global passenger vehicle fleet until 2030 (Figure 3). The impacts of potential activity strategies—including mode shift from LDVs to public transit and reduction of passenger travel owing to better land-use planning—can place LDV emissions on a downward trajectory. These policy options are discussed in greater detail in Chapter 6.

History has demonstrated that energy efficiency technologies can be effectively applied across markets given the global nature of the auto industry. Although there may be challenges in applying certain technologies in different markets, ICCT's involvement in technology assessment studies in the United States, Europe, and China gives us confidence that near-term cost-effectiveness and payback periods are comparable throughout the major vehicle markets of the world. For example, recovered fuel costs due to improved fuel efficiency associated with standards in the United States, China, and Europe have resulted in payback periods ranging from one to five years.[12, 13, 14, 15]

Although electric-drive vehicles are expected to play a minor role in the reduction of oil consumption and GHG emissions out to 2030, it is important to set the stage for their eventual large-scale adoption. While vehicles powered by internal combustion engines are far from the limits of efficiency, meeting the 2050 GHG reduction targets even as vehicle activity continues to grow will require a major switch to electric-drive vehicles powered by electricity and hydrogen generated using renewable energy sources. As part of the *Potential* trajectory, this study assumes that electric-drive vehicles will form a small but not insignificant share (up to 9 percent) of new-vehicle sales by 2030, providing a pathway for much faster uptake after 2030.

HEAVY-DUTY VEHICLE EFFICIENCY

Because of strong growth in truck activity, especially in emerging markets such as China and India, it is expected that global heavy-duty vehicle (HDV) emissions will more than double in the absence of mitigating policies. Even assuming adopted and pipeline policies, the share of HDV oil consumption and GHG emissions among the total transportation sector is expected to grow between 2010 and 2030.

National efficiency standards for HDVs—including both heavy-duty trucks and buses—have a much briefer regulatory history than LDV standards. Setting HDV efficiency standards is significantly more challenging than for LDVs. HDV fleets are extremely diverse in terms of vehicle size and configuration as well as usage patterns. The issues that must be addressed include the metric used to measure fuel economy or GHG emissions, the specific vehicles to be regulated, test methods to verify compliance, and methods for enforcement. Because of these challenges, HDV efficiency standards have just begun to be proposed and adopted in some of the major vehicle markets in the world, with even the first of such national standards not yet implemented. As a result, the anticipated reductions from these policies are not nearly enough to offset the projected doubling in global HDV emissions between 2000 and 2030 that would occur in the absence of these policies.

Japan was the first country to introduce such standards in 2005, even though they will not fully take effect until 2015. The United States finalized HDV efficiency standards in 2011 that will apply to vehicles starting in model year 2014. Canada has proposed standards equivalent to the U.S. ones, and Mexico is currently conducting active discussions to do the same. Europe has adopted standards for light commercial vehicles that will be manufactured between 2017 and 2020 but nothing for heavier vehicles, which account for a much larger share of oil consumption and emissions. China adopted an industry standard for minimum HDV efficiency in 2011 and has proposed a national new fleet average fuel consumption standard for HDVs. Additionally, though not modeled in this analysis, in-use programs are beginning to take shape. For example, starting in 2012, California requires long-haul tractors and 53’ box-type trailers—the highest fuel-consuming segment of heavy-duty vehicles—to comply with technology-specific requirements for aerodynamics and low rolling resistance tires.

Figure 4 shows the effects of policies that have been adopted or are under development, along with potential policies to reduce HDV emissions. Adopted and pipeline policies are expected to reduce oil-equivalent consumption and GHG emissions by 1.7 Mboe/day and 0.38 $GtCO_2e$ in 2030. As a result of delayed implementation of regulatory standards and technology potential, the anticipated emission reductions from these policies are not nearly enough to offset the projected doubling in global HDV emissions between 2000 and 2030 that would occur in the absence of these policies. Despite the relatively small benefits from policies adopted to date, there is substantial potential to reduce HDV emissions through vehicle efficiency, mode shift, and activity reduction policies and strategies. The benefits from HDV efficiency improvements will only take full effect after 2030 as new and more-efficient vehicles are incorporated into the fleet and zero-carbon technologies become cost-effective. Vehicle efficiency potential combined with mode shift and activity reduction could offset the growth in vehicle activity and stabilize HDV emissions at 2015 levels.

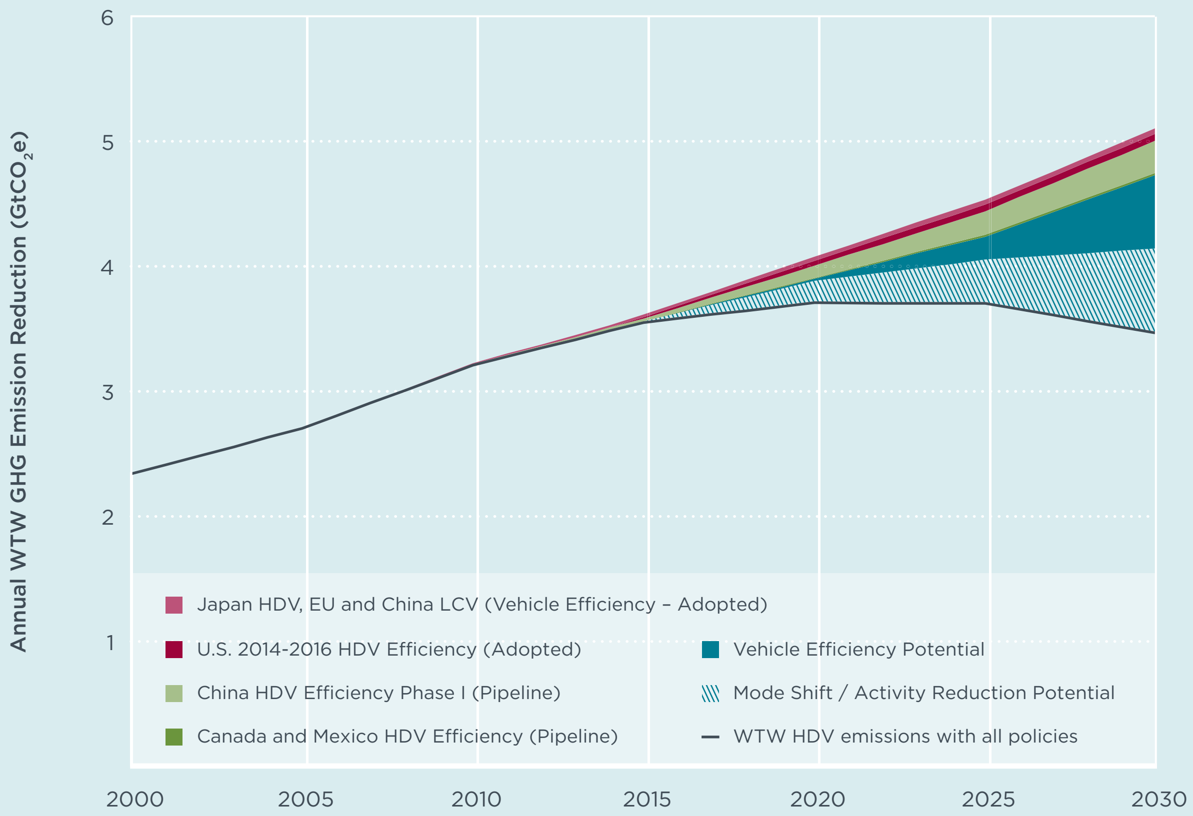

FIGURE 4. Policy Impacts on Global HDV Emissions

Studies by the National Academy of Sciences and TIAX for the U.S. market and studies by AEA-Ricardo and TIAX for the European market have shown a potential for 40 to 50 percent reduction in fuel consumption rates by 2020 for most types of HDVs. IEA has indicated similar results.[16] While payback periods vary by regulatory design, vehicle type, and region-specific activity patterns, HDV standards in this time frame typically have payback periods of one to four years. Because the stringency of initial regulatory efforts has been less ambitious than the potential would suggest, and most major jurisdictions will not have meaningful requirements until 2020, there is a lag in realizing the full near-term potential for this mode. As a result, the *Potential* trajectory in this analysis assumes an annual rate of reduction in fuel consumption of 3.5 percent for all new HDV classes (see Chapter 2 for more details). Owing to the longer regulatory time frame associated with developing HDV standards, the analysis of additional potential for reducing emissions from this mode assumes that these measures will begin to take effect in 2020 for the regions highlighted in this report (including those with regulations in place) and 2025 for other regions.

MARINE AND AVIATION

Marine and aviation emissions accounted for about a quarter of global transportation-related GHG emissions in 2010 and, according to this analysis, represent about 35 percent of the expected growth in global transportation emissions between 2010 and 2030. This already takes into account the emission reductions from the Energy Efficiency Design Index (EEDI). Approved by the International Maritime Organization (IMO) in 2011, the EEDI will improve the efficiency of new marine vessels by 25 percent by 2025.

Since a large share of marine and aviation activity crosses international borders, and national authority to regulate it tends to be limited, global policies are important to reducing emissions from these modes. For the most part, discussions of new fuel efficiency and CO_2 standards for marine vessels and aircraft have been held within the IMO and the International Civil Aviation Organization (ICAO), respectively. These bodies have also been the locus of discussion of market-based mechanisms to reduce emissions from aircraft and marine vessels. In addition, the European Union has included aviation and is considering including the marine sector in its Emission Trading Scheme (ETS), although there is uncertainty about the level of emission reductions that will actually occur within the transportation sector.

Adopted and pipeline policies for the combined marine and aviation sectors will reduce energy consumption and emissions by 2.2 Mboe/day and 0.43 $GtCO_2e$ in 2030, with 65 percent of these reductions coming from marine vessels. Because of the long timelines for regulatory development and adoption and the slow fleet turnover of large ships and aircraft, the bulk of reductions from adopted and pipeline policies will accrue after 2030 as more efficient vessels and aircraft become a predominant share of the fleet. By maximizing the technical and operational potential of marine vessels and aircraft, additional reductions of 1.9 Mboe/day and 0.37 $GtCO_2e$ in 2030 could be achieved.

FUELS

In contrast to the proven ability of vehicle efficiency regulations to result in significant emission reductions, there is substantial uncertainty about the effectiveness of policies to accelerate the development and deployment of low-carbon biofuels by 2030. Many regions have already implemented biofuel subsidies and mandates; these policies are intended to serve a variety of purposes, among them climate change mitigation, national energy security, and promotion of local agriculture. However, given a combination of legitimate concerns that crop-based biofuels can harm food security, slower than anticipated commercialization of 'advanced' biofuel technologies, and dispute about the legality of some policies, it is difficult to assess with confidence how the market will develop within the 2030 timeframe of this report.

Furthermore, the savings delivered by genuinely low-carbon fuels may be at least partly offset by predicted increases in the carbon intensity of fossil fuels. Between a lack of consensus in how to assess the life-cycle carbon effects of different fuel pathways, open questions about the effects of biofuel policies on food production, and concern about the ability to develop and commercialize truly low-carbon biofuels, there is currently a degree of uncertainty around the near-term carbon savings potential from fuels policies that is greater than uncertainties about the vehicle efficiency policies considered in this analysis. Rather than attempt to speculate on future outcomes based on insufficient evidence before the policy environment has settled, in general it is more appropriate for the near-term scope of this analysis not to assume global emission reductions from liquid fuels (except for sugarcane ethanol in Brazil—see Chapter 5 for details).

This analysis assumes that electricity and hydrogen, other options to reduce the carbon content in fuels, are primarily limited by commercialization of new vehicles, although the prospects for reducing the carbon content of these fuels also grow over time. While the near-term trajectory for the biofuel industry is unclear, if the right pathways can be targeted in the longer term there is real potential to achieve substantial carbon savings, to reduce fossil fuel consumption and to boost the rural economy.

MODE SHARE AND VEHICLE ACTIVITY

ICCT partnered with the Institute for Transportation and Development Policy (ITDP) to assess the potential for near-term strategies to achieve emission reductions through shifting passenger and freight traffic to more-efficient modes and reducing the amount of travel by motorized transportation. In order to quantify the impacts of policies intended to shift vehicle activity to more-efficient modes (often called mode shift), ITDP analyzed fully and partially funded transit investments using a project-by-project approach. These projects feature investments in improved bus systems called bus rapid transit (BRT), as well as conventional buses and passenger rail. The project-by-project analysis encompasses more than 100 projects in the main regions highlighted in this report, and it is the basis of the emissions reductions included in the *Pipeline* trajectory. For each transit project, the analysis considers the added capacity (in terms of passengers/day), average trip length, and assumed level of activity shifted from private automobiles. Because of difficulties in separating out historical benefits, this analysis groups the impacts of all projects—even those begun or completed in the past decade—into the *Pipeline* trajectory. In addition, the EU ETS is considered as an adopted policy and estimated to reduce air travel in the EU by about 3 percent in 2030. In the trajectory drawn from pipeline policies, this reduction in air travel is extended globally.

While there is substantial variation in the share of public transit across countries, ranging from more than 65 percent in India to less than 10 percent in the United States, trends suggest that the public transit share of global passenger activity will decrease substantially in the coming years.[17] In the United States, Mexico, Australia, and the EU-27, recent transit investments are expected to maintain public transit's share of activity; however, transit investments in rapidly growing countries like China, India, and Brazil have thus far not kept pace with passenger vehicle activity. For freight rail, the United States, Canada, and Australia have the highest shares because of the relatively long distances traveled by commercial freight, a rail infrastructure almost entirely dedicated to freight traffic, the predominance of bulk (and heavier) commodities, and a long history of investment in freight rail infrastructure.

The policy potential for mode shift and vehicle activity reduction measures is more difficult to estimate than potential for vehicle efficiency improvements owing to a combination of less regulatory certainty, more complex policy packages needed, poor data quality, and fewer recent examples of comprehensive policy best-practice packages to draw upon from around the world. The trajectory stemming from potential policies assumes that the progress observed in ITDP's project-by-project analysis of public transit investments can be expanded and accelerated through a combination of expanded infrastructure and targeted fiscal and incentive measures. It also assumes increases in freight rail mode share and slight overall reductions in passenger and freight activity. Future analyses will need to rely on more data-focused methods to refine the assumptions in this report.

As illustrated in Figures 3 and 4 above, since growth in vehicle activity and shipping plays the most important role in increasing global emissions, mode shift and activity reduction policies for passenger and freight transportation have a major role in reducing oil consumption and GHG emissions from the transportation sector. This analysis estimates that those policies could result in global oil consumption and GHG emission reductions of 6.6 Mboe/day and 1.3 $GtCO_2e$ in 2030.

SECTOR AND COUNTRY COMPARISON

Policy progress and baseline emissions growth differ substantially across transportation modes (Figure 5). Thanks to adoption of ambitious LDV efficiency standards in major vehicle markets, the share of LDVs in total transportation emissions is expected to decrease, although absolute emissions will increase. Because emissions and fuel economy standards for HDVs are just starting to be implemented for the first time, they tend to be less ambitious for these vehicles. As a result, adopted and pipeline policies for HDVs will not do as much to offset growth in truck activity. By 2030, the HDV sector will account for the largest share of transportation emissions. The marine and aviation sectors are expected to follow similar growth trends as seen in the past decade, although adopted and pipeline policies will offset some of the expected growth in transportation activity.

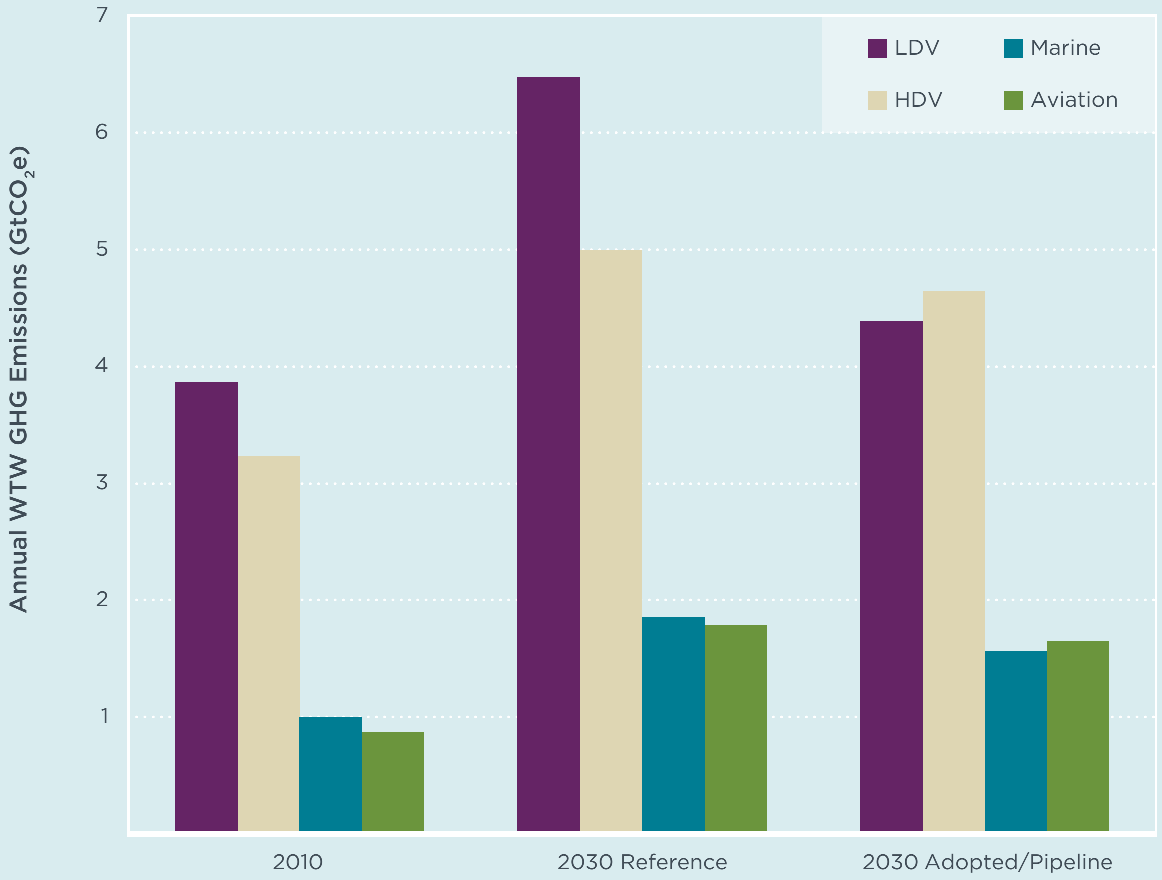

FIGURE 5. Impact of Adopted and Pipeline Policies by Mode

Figure 6 illustrates GHG emission reductions in 2030 from adopted and pipeline policies in different regions relative to the reference trajectory. Over all the regions analyzed, adopted and pipeline policies are expected to reduce in-country transportation emissions by 7 to 33 percent in 2030 compared to not implementing these policies. The contributions of regions to total GHG emission reductions depend not only on policymaking progress but also on total vehicle activity. Due to a combination of large vehicle fleets and leadership on policy, China, the United States, and Europe are responsible for the large majority (69 percent) of expected emission reductions from adopted and pipeline policies. Marine and aviation account for another 15 percent, and other regions account for the remaining share of emission reductions.

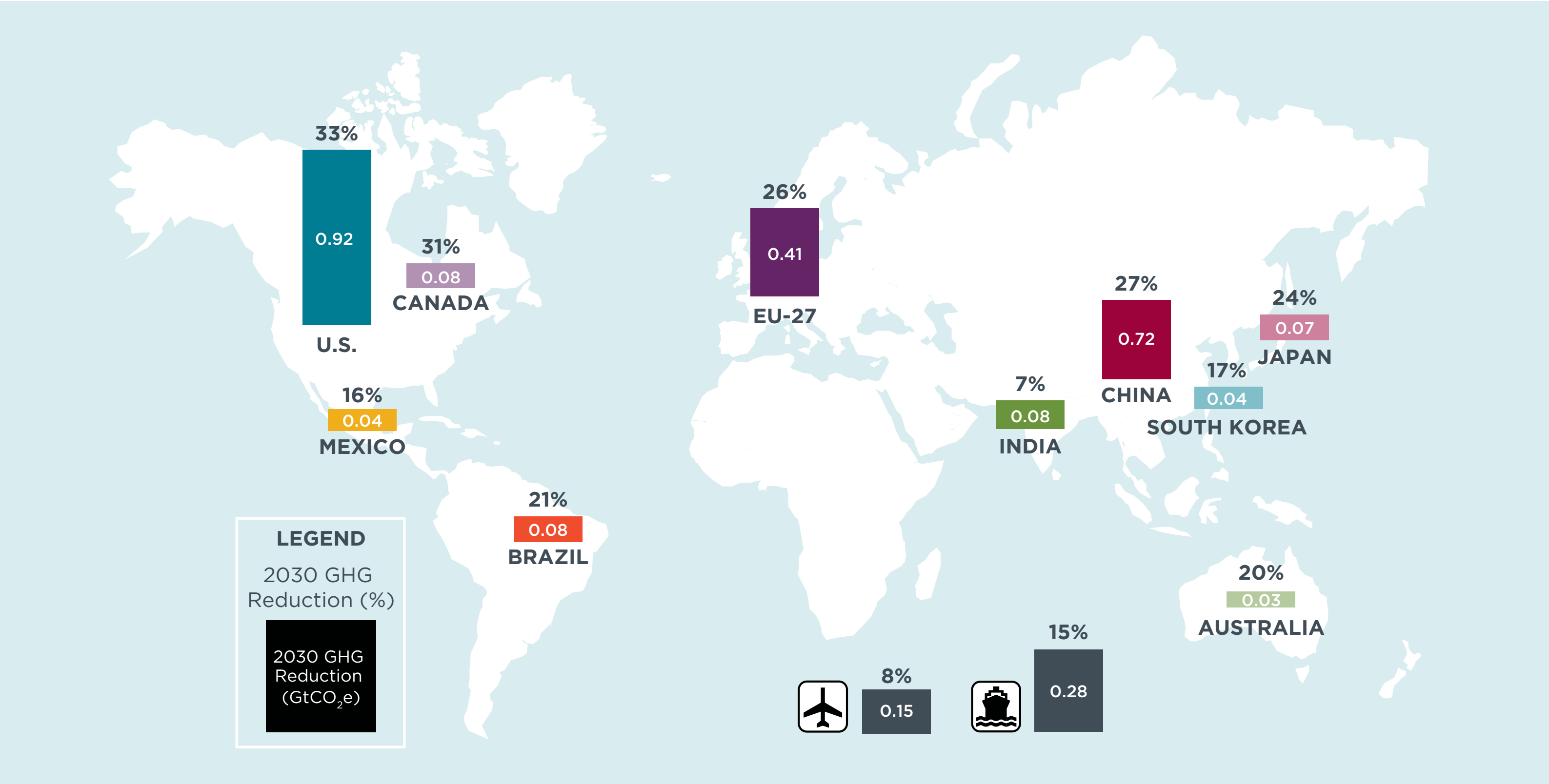

FIGURE 6. Adopted and Pipeline Emission Reductions in 2030 by Region

CONCLUSION

Standards that improve the efficiency of vehicles have demonstrated their capacity to achieve tremendous reductions in oil consumption and GHG emissions from the transportation sector. Policy progress in China, Europe, the United States, Japan, Canada, and South Korea, as well as gains in improving the efficiency of global shipping fleets, is already starting to achieve important reductions in transportation emissions. There is still much to be done to finalize the regulatory and other policy efforts under way, but the work completed to date lays a strong foundation and demonstrates a widespread commitment to further progress. Extending policies to improve vehicle efficiency to all transportation modes and to additional regions would bring significant additional benefits in 2030 and even more in future years. Although this analysis is conservative with respect to the near-term benefits of electric-drive vehicles and low-carbon fuels—technologies that are still in the development and commercialization stages—their longer-term potential after 2030 could be substantial. In order to achieve the ambitious reductions in emissions and fuel consumption needed in the 2030-50 time frame, the market and regulatory conditions need to be primed for the eventual large-scale deployment of electric-drive vehicles powered by renewable energy sources; and the development and commercialization of technologies to supply biofuels that deliver significant life-cycle carbon savings across the whole system—while not jeopardizing food security for a growing population, biodiversity, or other ecosystem services.

Many governments, especially at the local level, have a stated commitment to reduce the share of transportation activity that is captured by private passenger cars. There has been tremendous progress in the countries highlighted in this report and in cities around the world to shift to less energy-intensive modes, including bicycles and walking as well as buses and rail, and increasing investment has been made in more sustainable mobility patterns. While no new technologies are needed, more investment and policy action is necessary to change substantially the way people and freight move. Widespread development of well-designed public transit and freight rail infrastructure alongside fiscal and regulatory policies to discourage the use of private automobiles, short- and medium-haul aviation, and long-distance trucking could change the car and truck growth trends that are driving emission increases. More efficient land development patterns and infrastructure investments would enable substantial activity reduction and shifts to less energy-intensive modes, avoiding the lock-in of high energy intensity for generations to come.

This analysis demonstrates that near-term policies have the potential to stabilize global oil consumption and GHG emissions in the transportation sector. Achieving and sustaining the downward trajectory required to limit atmospheric temperature increases to two degrees Celsius will, however, require all available tools to reduce carbon emissions and oil consumption from transportation, including increased vehicle efficiency, a transformation of vehicle technologies and fuels, and policies to promote more sustainable passenger and freight modes that reduce reliance on private cars and heavy-duty trucks.

1. ANALYTICAL FRAMEWORK

This analysis considers three policy trajectories based on current and potential policy developments in each main region highlighted in this report and globally. Each policy trajectory includes a number of emission reduction strategies to *improve* the efficiency of vehicle fleets, marine vessels, and aircraft; *shift* transportation activity to less energy-intensive modes; and *avoid* transportation activity through more effective spatial, logistical, and communications systems. In order to estimate the effects of different policies and strategies, this analysis relies on the Global Transportation Roadmap model developed by the ICCT.

POLICY TRAJECTORIES

The policy assessments in this analysis evaluate oil consumption and GHG emission impacts of adopted, pipeline, and potential policies globally and in each of the world's ten largest vehicle markets. Emission reductions from near-term policies are estimated relative to a reference trajectory, in which future mode shares and activity growth are consistent with historical and socioeconomic trends. Historically, the efficiency of new passenger vehicles has improved in some regions yet worsened in others depending largely on consumer preferences with respect to power and size. In contrast, most regions have experienced modest improvements in the efficiency of new freight-hauling trucks over the past decade (generally on the order of 1 to 2 percent per year). Since the purpose of the reference trajectory is to quantify the emission reductions of recently adopted policies, it does not assume improvements in new passenger vehicle efficiency after 2000 in the absence of these policies. Historical improvements in new freight truck and aircraft efficiency are considered. For each region and globally, policies are grouped into three trajectories:

> **ADOPTED** Includes all existing, enforceable, and finalized regulations published in official government publications and adopted from 2000 to present but assumes no autonomous changes in vehicle efficiency for modes other than aviation or further penetration of electric-drive vehicles or lower-carbon fuels.
>
> **PIPELINE** Includes formally announced or proposed regulations, by a government agency with relevant regulatory authority, with sufficient specificity to estimate potential benefits (e.g., quantitative target and timeline). Policies in the pipeline include vehicle efficiency and/or GHG standards for passenger vehicles, heavy-duty trucks, aircraft, and marine vessels; market-based measures for aircraft and marine vessels; as well as fully and partially funded projects to increase public transit infrastructure.
>
> **POTENTIAL** Includes a more complete range of best-practice vehicle efficiency, mode shift, and activity (demand for travel or shipping) reduction strategies that are feasible from a technical and operational perspective out to 2030, resulting in a trajectory that is ambitious but achievable. This analysis does not consider political willingness to implement these policies and strategies but includes a reasonable time lag for policy development and adoption, as well as

infrastructure development. For those countries with specific policies in place or under way, additional potential is calculated to 2030 only beginning after the close of the current regulatory time frame. In addition to improved vehicle efficiency, this trajectory includes shifts from passenger vehicles to mass transit and nonmotorized modes, as well as shifts from long-distance trucking to freight rail. Complementary policies to reduce the average length of urban trips and to improve logistics operations are also considered. While additional reductions could likely be achieved through more comprehensive logistics improvements and a widespread application of information, communication, and pricing technologies to manage transportation supply and demand, these measures were not assessed in the analysis.

For all three trajectories, the marine and aviation sectors are considered at the global level. Table 3 includes a summary of adopted, pipeline, and potential policies for the main regions considered in this analysis.

EMISSION REDUCTION STRATEGIES

The Roadmap model considers the efficiency and carbon intensity of the full transportation system, including the efficiency of new and in-use vehicle fleets, the share of more or less carbon-intensive modes, and overall demand for transportation services. This approach of incorporating all elements of transportation system efficiency has been referred to as the Avoid-Shift-Improve (A-S-I) framework (Figure 7).[18] The A-S-I framework is used by the Asian Development Bank, the Inter-American Development Bank, the International Energy Agency, German Society for International Cooperation (GIZ), the 68-member Partnership on Sustainable Low Carbon Transport, and many other institutions as a key tool for analysis and decision making on transportation projects, programs, and policies. This analysis also includes a fourth classification to this framework to account for policies and strategies that will transform the vehicle fleet and fuel systems to zero-emission technologies. The key difference between *Improve* and *Transform* strategies is that *Improve* measures rely on the expansion of existing technologies that have already been proven to reduce emissions: for example, hybrid internal combustion engine (ICE) vehicles, sugarcane ethanol in Brazil, and bus rapid transit (BRT) systems. In contrast, *Transform* strategies involve the development and introduction of technologies and systems that have not yet reached large-scale implementation or market adoption: for example, plug-in hybrid, battery electric, and fuel cell vehicles; second-generation biofuels (including cellulosic ethanol and algae-derived biodiesel); and electrified freight truck corridors supplied with electricity from renewable sources.

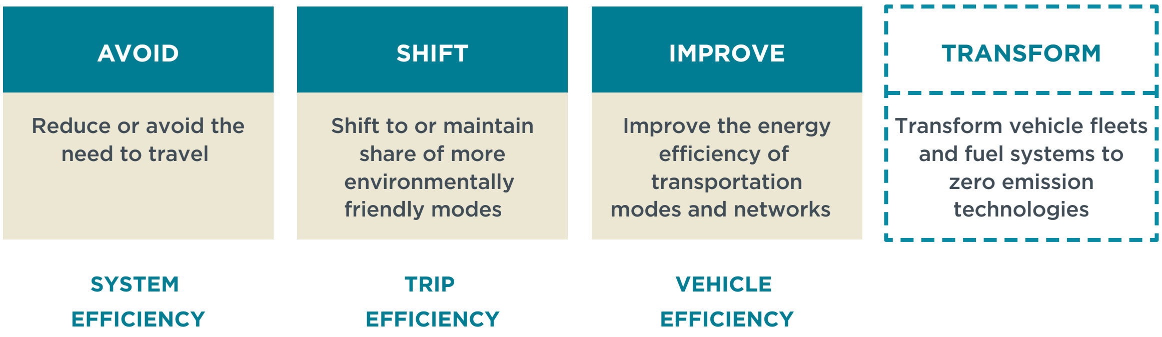

FIGURE 7. Avoid-Shift-Improve-Transform Framework

The ICCT's work has long focused on the Improve (and Transform) portion of this framework—reducing the carbon impacts of vehicles and fuels. ICCT has worked closely with the Institute for Transportation and Development Policy (ITDP) to determine the policy strategies available to achieve emission reductions from improving trip and system efficiency. Table 2 describes the emission reduction strategies considered in this analysis and how those strategies relate to the A-S-I(-T) framework.

TABLE 2. Emission Reduction Strategies

Strategies	Avoid	Shift	Improve	Transform
On-road vehicle efficiency improvements[d]			●	●
Marine and aviation sector improvements	●	●	●	
Low-carbon fuels			●	●
Land-use planning	●	●		
Travel demand management	●	●		
Sustainable transportation infrastructure	●	●		
Logistics improvements	●			
Fiscal measures	●	●	●	

GLOBAL TRANSPORTATION ROADMAP MODEL

The ICCT developed the Global Transportation Roadmap model, which draws upon the best available data for global and national transportation emissions and policies, to quantify the potential of current and future transportation sector policies to reduce energy consumption and emissions. The model was developed to provide insights on questions most critical to government regulators, policymakers, and other stakeholders, including:

- What is the current growth rate in energy and GHG emissions from the transportation sector by mode and by region?
- What are the energy and emission benefits of past and existing transportation policies?
- What is the potential to reduce further energy consumption and GHG emissions from the transportation sector?
- How do countries compare in terms of vehicle efficiency and mode shares?

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[d] For the most part, the emission reductions from vehicle efficiency and fuels that are quantified in this analysis can be categorized as Improve strategies; however, reductions from increased market penetration of electric-drive passenger vehicles (powered with low-carbon electricity) are assessed as Transform measures.

Using socioeconomic forecasts in which population, gross domestic product (GDP), and fuel prices are central, the model estimates future transportation activity and mode shares. By relying on exogenous input parameters related to vehicle technology, efficiency, and fuel shares, the model estimates corresponding well-to-wheel (WTW) emissions to 2050. The following points characterize the Roadmap model:

POLLUTANTS Selected GHGs (CO_2, CH_4, and N_2O) and local air pollutants (NO_x, exhaust PM_{10} and $PM_{2.5}$, CO, black carbon, and SO_2). Please refer to Appendix A for a more in-depth discussion of the selection of GHGs in this analysis. The Roadmap's calculations of WTW emissions of GHGs and local air pollutants include the fuel life cycle, comprising the refining, processing, distribution, and combustion of fuels. The Roadmap does not assess life-cycle emissions from vehicle manufacturing, distribution, or end-of-life (i.e., disposal or recycling), nor does it examine the transportation infrastructure life cycle. This report focuses on the GHG outputs from the model. A subsequent ICCT report will address the transportation-related health impacts of local air pollutants.

MODES Light-duty vehicles (LDVs), buses, motorcycles, three-wheelers, heavy-duty trucks (HDTs, subdivided into light, medium, and heavy HDTs), passenger and freight locomotives, passenger aircraft, and freight marine vessels. This report includes emissions from all transportation modes, but it does not evaluate policies to improve locomotive efficiency, which may be a subject of future analyses.

COUNTRIES The geographical focus is on the ten countries/regions with the greatest annual new-vehicle sales. This report includes a detailed policy assessment for each of the following countries/regions: the United States, the EU-27 (the 27 member states of the European Union), China, India, Japan, Brazil, Canada, South Korea, Mexico, and Australia. The model also analyzes six broader regions: the rest of Latin America, rest of Europe, rest of the Asia-Pacific, Russia, Africa, and the Middle East.

TIME HORIZON 2000 to 2050, in five-year increments. In order to inform upcoming policymaking efforts, this report focuses on near-term regulatory time frames out to 2030. In so doing, the analysis is limited to the deployment of vehicle technologies currently being commercialized, and thus it will avoid making speculative assumptions about dramatic transformations in the transportation sector.

FUEL TYPES Gasoline, ethanol (grain, sugarcane, and cellulosic), diesel (conventional and low-sulfur), biodiesel (oil-based and ligno-cellulosic), compressed natural gas (CNG), liquefied petroleum gas (LPG), hydrogen, electricity, jet fuel, and residual fuel.

VEHICLE TECHNOLOGIES Conventional, hybrid, plug-in hybrid, battery electric, and fuel cell vehicles.

Simplified emission calculation methods are illustrated in Figure 8. Changes in land-based passenger and freight transportation activity are determined from changes in population, GDP, and relative fuel price forecasts, while aviation and marine activity are based on International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO) projections. Appendix E includes the projections of GDP, population, and total GHG emissions by region for the *Adopted* trajectory. Vehicle activity by mode is then determined from total passenger or freight activity and load factors. The breakdown of vehicle activity by technology type is determined from vehicle sales and a turnover algorithm. Vehicle stock and sales are calculated as model outputs and can be used to validate and calibrate the model. Fuel consumption is the product of vehicle activity and fleet-average fuel efficiency, which is estimated using new-fleet efficiency and a turnover algorithm. Due to a lack of globally consistent forecasts for congestion and roadway capacity, the model considers neither rebound effects from increased fuel efficiency nor decreased activity as a result of traffic congestion (though these effects may cancel out to some degree); however, the model does include assumptions to convert test-cycle vehicle efficiency to in-use efficiency. The breakdown of fuel consumption by type is determined from fuel blends. Tank-to-wheel (TTW) emissions of CO_2 are calculated as the product of fuel consumption (by type) and carbon content of fuels, while TTW emissions of other pollutants are calculated as the product of TTW emission factors and either vehicle activity (for on-road modes) or transportation activity (for rail and aviation). Average TTW emission factors are based on vehicle emission standards and a turnover algorithm. Well-to-tank (WTT) emissions of all pollutants are calculated as the product of fuel consumption (by type) and WTT emission factors. Emissions from marine vessels are estimated directly from IMO projections.

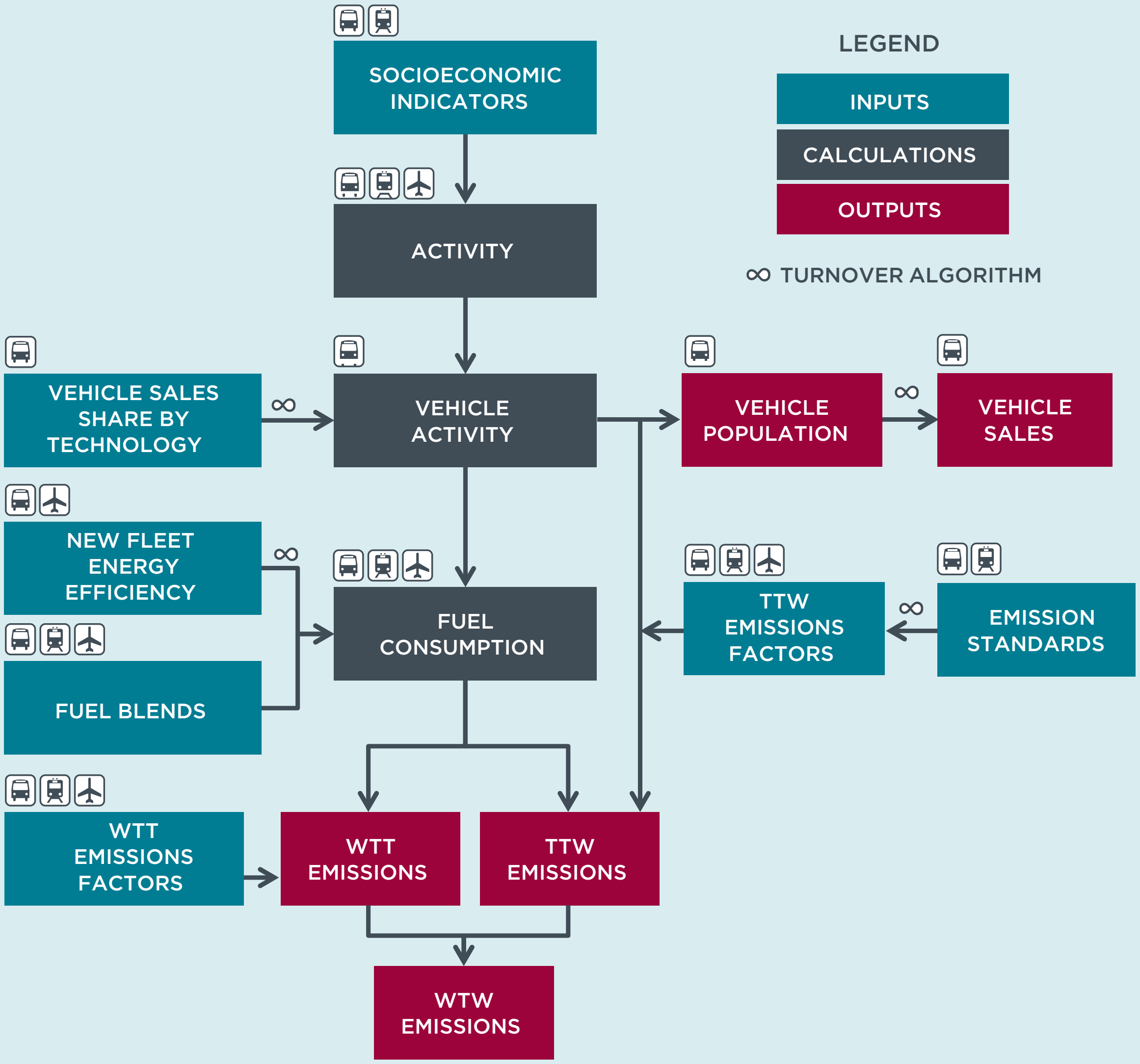

FIGURE 8. Simplified Emission Calculation Methods

The ICCT has collaborated closely with government agencies in each of the countries/regions highlighted in this report to ensure that the model includes the most representative and credible publicly available data. The ICCT also collaborated extensively with the ITDP on the analysis of mode shift and activity reduction policies and strategies, and with the International Energy Agency (IEA) on data collection and emissions modeling. Many updates were done to the Roadmap model using the IEA's Mobility Model (MoMo) for areas where the Roadmap model lacked data. The input parameters and model outputs from the Roadmap model were compared against MoMo data, and the results of such comparisons are available together with the Roadmap model documentation. The Roadmap model and supporting documentation are available for download on the ICCT's website.

NEXT STEPS

This analysis provides regulators and policymakers with a near-term roadmap of the reductions in oil consumption and GHG emissions that are possible through adoption of best-practice transportation policies. An upcoming analysis will consider the policy pathways for reducing local air pollutant emissions from the transportation sector and will quantify the health benefits of these emission reductions. Beyond these two key studies, future work can build on the results and framework of this analysis, including:

- Assessment of the costs associated with near-term policy potential. While the *Potential* trajectory in this analysis is based on literature and technical studies of cost-effective technology potential for vehicles, an additional assessment could quantify the costs to demonstrate more fully the cost-effectiveness of this policy pathway.
- An extension of the analysis to 2050. The Global Transportation Roadmap model, which is currently available on the ICCT's website, will allow interested parties to formulate pathways to achieving transportation GHG targets, including emission pathways consistent with a two-degree trajectory if assumptions are made about the allocation of reductions across sectors. The framework in this analysis can be used to compare progress across regions and modes, assess the long-term effects of new and proposed transportation policies, and continuously evaluate the gap against a two-degree trajectory.
- Impacts of an eventual global fuel economy standard harmonization (especially in terms of stringency level).
- Focus on potential transformations within the transportation sector—which could spur critical reductions in emissions after 2030—such as electric-drive vehicles, low-carbon and alternative fuel pathways (including hydrogen and electricity), and changes in urban development that drive more substantial shifts to less energy-intensive modes.
- Further work is needed to improve the characterization of certain aspects of transportation emission reduction potential. Baseline data on transportation activity remains subject to considerable uncertainty because of uneven monitoring and reporting. Although traffic congestion is growing more severe across much of the world, degrading in-use vehicle fuel economy under a business-as-usual case, these effects are not modeled owing to a lack of credible and globally consistent data. Similarly, wider application of information, communications, and pricing for active transportation

supply and demand management offers the potential to reduce traffic congestion without spurring induced travel demand. This policy pathway and other options that could influence in-use vehicle efficiency or freight logistics have not been evaluated here, except through limited sensitivity analysis. A more detailed analysis of the effects of mode shift and activity reduction strategies on in-use vehicle efficiency and socio-economic projections of transportation activity may be developed. While this analysis relies on the best available data, a more data-intensive method based on the observed effectiveness of different policies could increase the certainty of the results.

- Evaluation of explicit impacts of fiscal measures on transportation activity, mode shares, and vehicle efficiency.
- Potential for collaboration with country partners, particularly those in regions not highlighted in this report, to expand modeling capacity and run more detailed, country-specific analyses related to climate, energy, and health. These analyses could include the climate and health effects of transportation policies in countries with a high sales share of imported used vehicles.
- Potential for more collaboration with IEA's MoMo team to improve data and model capabilities.
- Policy updates for countries and modes to quantify emission and fuel consumption reductions as new policies are adopted or proposed.

TABLE 3. Policy Dashboard

Policy Area	Adopted	Pipeline	Potential
LDV Efficiency	U.S. – Model Year (MY) 2000–2011 NHTSA; 2012–16 / 2017–25 EPA/NHTSA EU-27 – PV 140 gCO_2/km by 2008; PV 130 gCO_2/km by 2015; LCV 175 gCO_2/km by 2017 China – LDV Phases I,II,III; LCV Phase I Japan – Top Runner approach MY 2010, 2015, and 2020 Brazil – LDV 2017 fiscal incentives Canada – CAFC LDV standards; GHG MY 2011–16 South Korea – Average Fuel Economy (AFE) program	EU-27 – PV 95 gCO_2/km by 2020; LCV 147 gCO2/km by 2020 China – LDV Phase IV India – LDV 20km/L by 2020 proposal Brazil – LDV 2017 fiscal incentives Canada – eq. U.S. 2017–25 Mexico – eq. U.S. 2012–16 Australia – LDV proposal	Main regions: MY 2015–30 (beginning at the close of the regulated time frame): PV and LCV improvements of 4% per year; motorcycle improvements of 1% per year. Other regions: MY 2020–30: PV and LCV improvements of 4% per year; motorcycle improvements of 1% per year
HDV Efficiency	U.S. – 2014–18 EPA/NHTSA California – Long-haul Truck GHG Regulation Japan – Top Runner approach MY 2015	China – Phase I Canada – eq. U.S. 2014–18 Mexico – eq. U.S. 2014–18	Main regions: MY 2020–30 (beginning at the close of the regulated time frame): 3.5% annual improvements for all classes of trucks and buses. Other regions: improvements start in 2025.
EVs	U.S. – ZEV mandate in California to 2025	-	Increasing growth in ZEV LDV sales market share of electric-drive technologies: 8–9% (U.S., Japan, Canada, all of Europe, China, South Korea, and Australia) to 1–2% for all other regions. PHEV sales market share from 1% to 5%.
Fuels	Globally no change in carbon intensity of liquid fuels. Brazil – Brazilian sugarcane is the exception, and GHG benefits are estimated for this pathway, historical increase in ethanol use.	Globally no change in carbon intensity of liquid fuels. Brazil – Increased share of ethanol consistent with national emissions inventory.	-
Aviation	EU – ETS Global – Annual improvements in new aircraft efficiency equal to natural improvements in reference trajectory.	Global – Market-based mechanisms (MBMs) (moderate) Global – ICAO CO_2 standard (moderate) – 1.6% annual improvements (2010–30).	Global – MBMs (aggressive) Global – ICAO CO_2 standard (aggressive) – 2.2% annual improvements (2010–30).
Marine	Global – EEDI	Global – MBMs	Global – SEEMP
Mode Shift	Adopted transit investments are included as part of the Pipeline trajectory.	Based on project-by-project analysis of fully and partially funded transit projects.	Potential transit, freight rail, and nonmotorized infrastructure improvements offset an increasing share of growth in LDV/HDT activity.
Activity Reduction	EU – ETS (aviation)	Global – MBMs (marine/aviation)	Potential logistics improvements and reduction in urban passenger trip distances. Global – SEEMP (marine) Global – MBMs (aviation)

2. ON-ROAD VEHICLES

Substantial improvements to on-road vehicles can be realized through known and existing technologies for engine, transmission, and driveline improvements, hybrid systems, lightweight materials, as well as better aerodynamics and rolling resistance. Conventional wisdom has held that consumers and especially commercial truck operators would demand fuel-efficient vehicles to reduce transportation costs. In reality, consumers and manufacturers have been unwilling to invest in fuel economy technologies unless they have less than a one- to two-year payback from fuel savings. As a result, in the absence of fuel economy or GHG regulations or incentives, trends in new-vehicle fuel economy have varied from market to market—from minor improvement to significant worsening—depending largely on fuel pricing and income growth.

Mandatory fuel economy standards for passenger vehicles are in effect for more than 70 percent of the global new light-duty vehicle market. Standards have a proven track record for achieving efficiency improvements. In order to secure overall reductions in fuel use and GHG emissions in the face of increasing vehicle travel, standards must be made continuously more stringent over time. Well-designed fiscal policies can greatly augment the benefits of standards (or even replace them in some cases), encouraging more efficient vehicle choices for passenger cars and more efficient use of the transportation system for freight.

FUEL ECONOMY AND FUEL CONSUMPTION

Options to improve vehicle efficiency include improved engine efficiency, reduced vehicle weight, improved aerodynamics, and reduced rolling resistance. Shrinking vehicle size provides an additional option to trim fuel consumption. Standards and incentives both increase fuel economy and lessen fuel consumption, terms that are often used in this report.

Fuel economy is a common regulatory metric that measures the distance traveled per unit of fuel consumed. Typical examples are kilometers per liter (km/L) or miles per gallon (mpg).

Fuel consumption is another common regulatory metric that is the reciprocal of fuel economy. It measures the unit of fuel consumed per distance traveled, usually expressed in liters per 100 kilometers (L/100 km). Rates of reduction for fuel consumption standards are proportional to reduction rates for GHG or CO_2 emissions, expressed as grams of pollutant per distance traveled.

Metrics for heavy-duty vehicles often include payload, either in terms of volume (m^3 or ft^3) or mass (ton). Metrics can be given as a ratio of payload and distance traveled per unit of fuel consumed (e.g., ton-mile per gallon) or the reciprocal ratio.

Because standards only affect new vehicles added to the fleet, the full impacts take years to be realized. These impacts increase over time as more efficient vehicles make up a larger share of the fleet. And as more stringent standards are implemented in the main vehicle markets, new technologies and innovation will eventually spread to other regions. However, while standards in the largest vehicle markets can help reduce the costs of efficiency technologies globally, it is important to note that local standards or effective vehicle incentive programs are still necessary in order to ensure their full incorporation into fleets in other markets. As mentioned above, efficiency improvements are typically undervalued by consumers. As a result, manufacturers may choose not to offer more efficient options or may use these technologies instead to increase, or offset increases in, vehicle power and size.

Additional policies, which are not directly quantified in this analysis, can accelerate and enhance the impact of vehicle efficiency standards and incentives. Fiscal measures, including higher fuel taxes, fuel-consumption-based vehicle fees, and vehicle scrappage programs, can help incentivize purchase of the most efficient vehicles and speed the turnover of the existing fleet. These types of programs, if well designed, increase the share of the vehicle fleet that is affected by efficiency standards, remove some of the least efficient vehicles from the fleet, and decrease the fleet-average vehicle size. Some of these policies may help promote a shift to more efficient transportation modes or a reduction in vehicle activity. Programs may also be designed to promote in-use vehicle efficiency, such as tire efficiency ratings, high-efficiency engine oil and lube applications, reductions in vehicle idling, more efficient driving behavior, and improved vehicle maintenance. Some transportation demand management strategies may also spur in-use efficiency through improvements in traffic flow and reductions in urban congestion.

Other initiatives and recent studies have evaluated the effects of policies on vehicle fuel efficiency. In particular, the Global Fuel Economy Initiative (GFEI), of which the IEA, the International Transport Forum (ITF), the FIA-Foundation, the ICCT, and the United Nations Environment Programme (UNEP) are members, seeks a 50 percent increase in the global fleet-average light-duty fuel economy by 2050.[19] IEA has recently released a technology roadmap for vehicle fuel economy that recommended a 50 percent increase in fuel economy for new light-duty vehicles by 2030, a 30 percent increase for heavy-duty trucks, and a 20 percent increase for motorcycles.[20] These improvements are less aggressive for light-duty vehicles but similarly aggressive for other modes as compared to the vehicle potential estimated in this analysis: 72 percent for light-duty vehicles, 27 percent for heavy-duty trucks, and 13 percent for motorcycles from 2010 to 2030.

LIGHT-DUTY VEHICLES

Table 4 describes the policies for light-duty vehicles (LDVs), which include passenger vehicles such as cars, minivans, and sport utility vehicles (SUVs) as well as light commercial vehicles (LCVs) and motorcycles (both two- and three-wheeled vehicles) in each main region in the *Adopted* and *Pipeline* trajectories, followed by the assumptions included in the *Potential* trajectory.

TABLE 4. Summary of LDV Efficiency Policies

Region	Policy	
United States	**ADOPTED**	Model Year (MY) 2000–2011 LDV Corporate Average Fuel Economy (CAFE) standard (NHTSA) MY 2012–16 LDV standard, 35.5 mpg / 250 gCO$_2$e/mile by 2016 (NHTSA and EPA)[21] MY 2017–25 LDV standard, 49.1 mpg—accounting for use of crediting provisions—or 163 gCO$_2$e/mile by 2025 (NHTSA and EPA)[22]
	PIPELINE	None
EU-27	**ADOPTED**	MY 2008+ voluntary agreement, 140 gCO$_2$/km MY 2015 PV standard, 130 gCO$_2$/km (EC 443/2009) MY 2017 LCV standards, 175 gCO$_2$/km[23]
	PIPELINE	MY 2020 PV target, 95 gCO$_2$/km (EC 443/2009, regulatory details by 2013)[24] MY 2020 LCV standards, 147 gCO$_2$/km (EC 443/2009)[25]
China	**ADOPTED**	MY 2005 LDV standard – per vehicle standard (Phase I) MY 2008 LDV standard – per vehicle standard (Phase II) MY 2015 LDV standard, 6.9 L/100km (Phase III, implementation under development) MY 2006 LCV standard, 9.42 L/100km; MY 2009 LCV standard, 8.46 L/100km (Phase I)
	PIPELINE	MY 2020 LDV standard, 5 L/100km (Phase IV, State Council goal)[26]
India	**ADOPTED**	None
	PIPELINE	MY 2020 LDV proposal, 20 km/L
Japan	**ADOPTED**	MY 2010 LDV standard, 15.1 km/L (Top Runner program) MY 2015 LDV standard, 16.8 km/L; minibuses, 8.9 km/L; LCVs, 16.8 km/L[27] MY 2020 PV standard, 20.3 km/L
	PIPELINE	None
Brazil	**ADOPTED**	2017 fiscal incentives for LDVs, 17.4 km/L Not modeled: voluntary LDV labeling program[28]
	PIPELINE	2017 fiscal incentives for LDVs, 18.8 km/L
Canada	**ADOPTED**	MY 1976–2006 Voluntary LDV Corporate Average Fuel Consumption (CAFC) standard MY 2007–10 Mandatory LDV CAFC standard MY 2011–16 LDV standard harmonized with U.S. EPA
	PIPELINE	MY 2017–25 LDV standard harmonized with U.S. EPA
South Korea	**ADOPTED**	MY 2012–15 LDV Average Fuel Economy (AFE) program, 17 km/L by 2015[29] Not modeled: MY 2012 PVs less than 1600cc, 14.3 km/L; PVs greater than 1600cc, 11.0 km/L
	PIPELINE	None
Mexico	**ADOPTED**	None
	PIPELINE	MY 2013–16 LDV standards harmonized with U.S. NHTSA
Australia	**ADOPTED**	None
	PIPELINE	LDV proposal expected in 2012, with finalization in 2013 (target not yet announced)
Main Regions	**POTENTIAL**	MY 2015–30 (beginning at the close of the regulated time frame): PV and LCV improvements of 4% per year; motorcycle improvements of 1% per year
Other Regions	**POTENTIAL**	MY 2020–30: PV and LCV improvements of 4% per year; motorcycle improvements of 1% per year

Figure 9 translates the passenger vehicle policies included in Table 4 above into average new-vehicle emissions. The figure shows adopted policies and historical performance (solid lines) and pipeline policies (dashed lines) described above for fuel efficiency and/or GHG emissions.

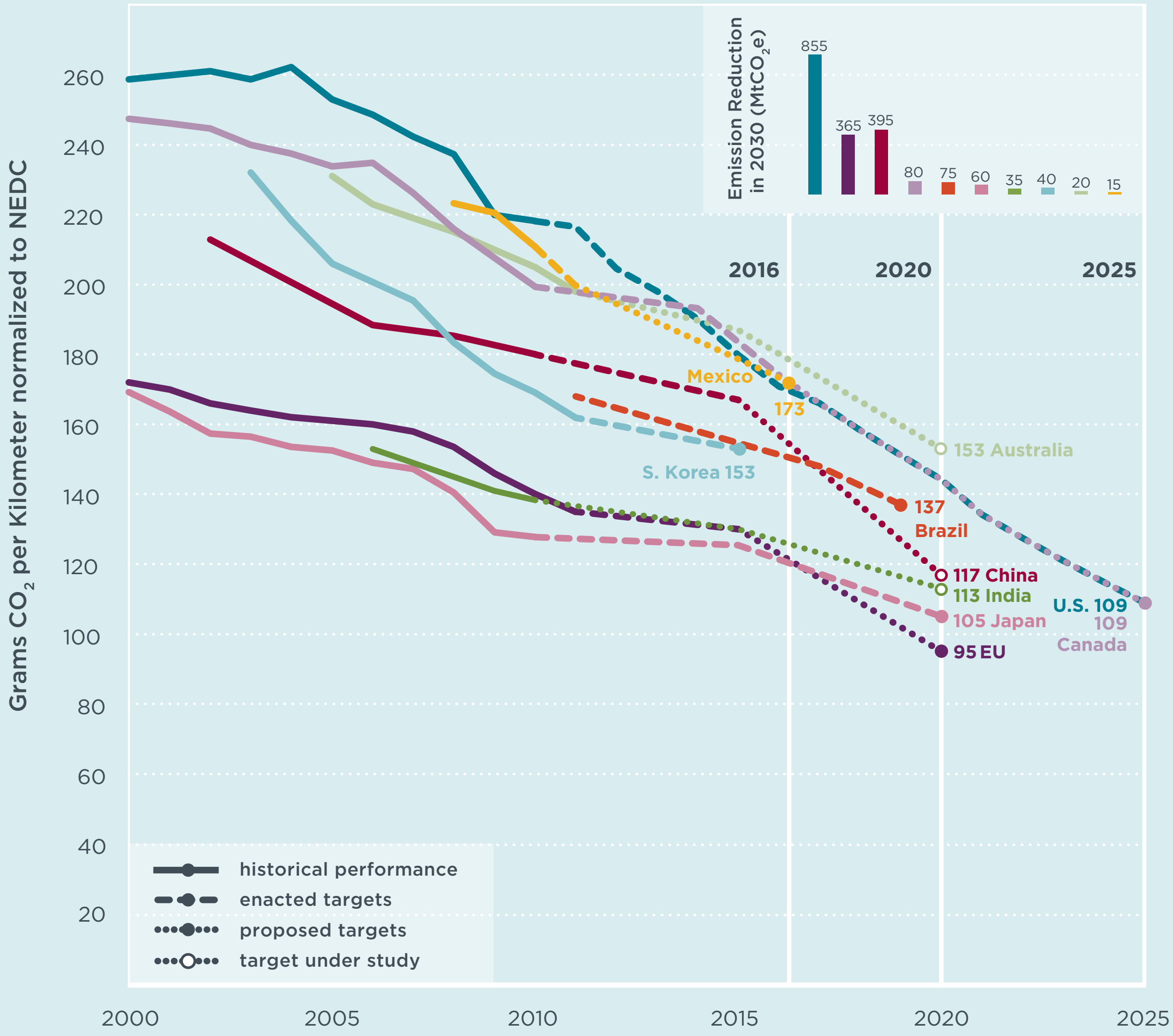

FIGURE 9. Comparison of LDV CO_2 Emission Rates

While Japan and Europe currently lead the world in terms of fleet-average fuel efficiency of passenger vehicles, U.S. standards are expected to achieve the greatest reduction in fuel consumption—a 42 percent reduction from 2011 to 2025. Because of the sheer size of its projected fleet and the fact that it starts from an inefficient baseline, the absolute reduction in emissions from the U.S. standards is expected to exceed 850 $MtCO_2e$ in 2030, assuming best practices for compliance and enforcement. The adopted and pipeline efficiency standards in China and the EU-27 are also expected to generate substantial reductions in 2030—between 360 and 400 $MtCO_2e$ each—and a total reduction in fuel consumption of 32 to 35 percent out to 2020. China's Phase III standards for LDVs will move from a per vehicle basis to the country's first-ever fleet-average fuel consumption standards, allowing for much more ambitious overall efficiency improvements. China is also currently the only country in the world to set fuel consumption standards for two- and three-wheelers, and Vietnam has two- and three-wheeler fuel economy standards in the pipeline. A China Phase II standard is under discussion for motorcycles and mopeds, but because no firm target has been set it is not included in the pipeline.

COST-EFFECTIVE POLICIES

History has demonstrated that energy efficiency technologies can be effectively applied across markets given the global nature of the auto industry. Manufacturers looking to reduce the number of platforms, lower production costs, and spread research and development costs among regions can take advantage of their global market shares. ICCT involvement in important technology assessment studies in the United States, Europe, and China gives us confidence that near-term cost-effectiveness is generally transferrable between the major vehicle markets of the world.

As an example, the U.S. EPA has invested millions of dollars of research into understanding the costs and potential benefits of passenger and heavy-duty vehicle standards over recent years. For passenger vehicles, adopted EPA and NHTSA standards will reduce CO_2 per kilometer emissions from new vehicles by approximately 50 percent out to 2025, an annual rate of reduction of 4.8 percent.[22] Taken together, the 2016 and 2025 standards will increase the average price of a new passenger vehicle by less than $2,700 and will save consumers $6,000 to $7,000 over the lifetime of the vehicle, a payback time of three to four years, at current U.S. gas prices (some of the lowest among the regions considered).[35] An extension of some of these studies to consider technologies in China and Europe found similar results.

Standards in other countries will not generate comparable benefits largely because of smaller fleet size, although adopted and pipeline policies tend to be somewhat less ambitious as well. Together, adopted and pipeline fuel efficiency standards for the new light-duty fleet are expected to generate annual oil reductions of 9.8 Mboe/day and emission cuts of 2 $GtCO_2e$ in 2030. There are no adopted policies included in this analysis for Mexico, India, and Australia, although both India and Mexico have policies in the pipeline, and Australia is expected to release a proposal this year. Brazil does not have fuel efficiency or GHG standards for LDVs, but it has recently adopted a tax incentive that takes vehicle efficiency into account and will likely achieve similar effects of those of a standard.[e]

As mentioned above, the United States, Europe, Japan, and China are pioneering global regulatory policies for LDVs. Figure 10 shows the annual rate of emission reduction implied by adopted and pipeline policies set in these regions. Adopted standards in the United States and Europe require close to 4 percent or greater annual reductions in fuel consumption or GHG emissions. The United States, which currently has a less efficient fleet than Europe or Japan, has set the most aggressive and longest-term standards, which will result in a 4.8 percent annual rate of reduction out to 2025. The ambitious target adopted by the State Council in China would help that country catch

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[e] Additional preregulatory steps are being taken in Brazil, including creating a vehicle-specific section in the country's Product Development Policy (PDP), an initiative by the Ministry of Development, Industry and Foreign Trade (MDIC) designed to promote efficiency, innovation, and competitiveness amid the global market, and conducting research studies on vehicle energy efficiency.

up with progress in other regions. Japan, which currently has the most efficient new-vehicle fleet in the world, has set the least ambitious standards. Even though Japan sets standards over a long time frame, these tend to be technology following rather than technology forcing. Tax incentives and driving conditions, however, help to foster overall fleet efficiency.

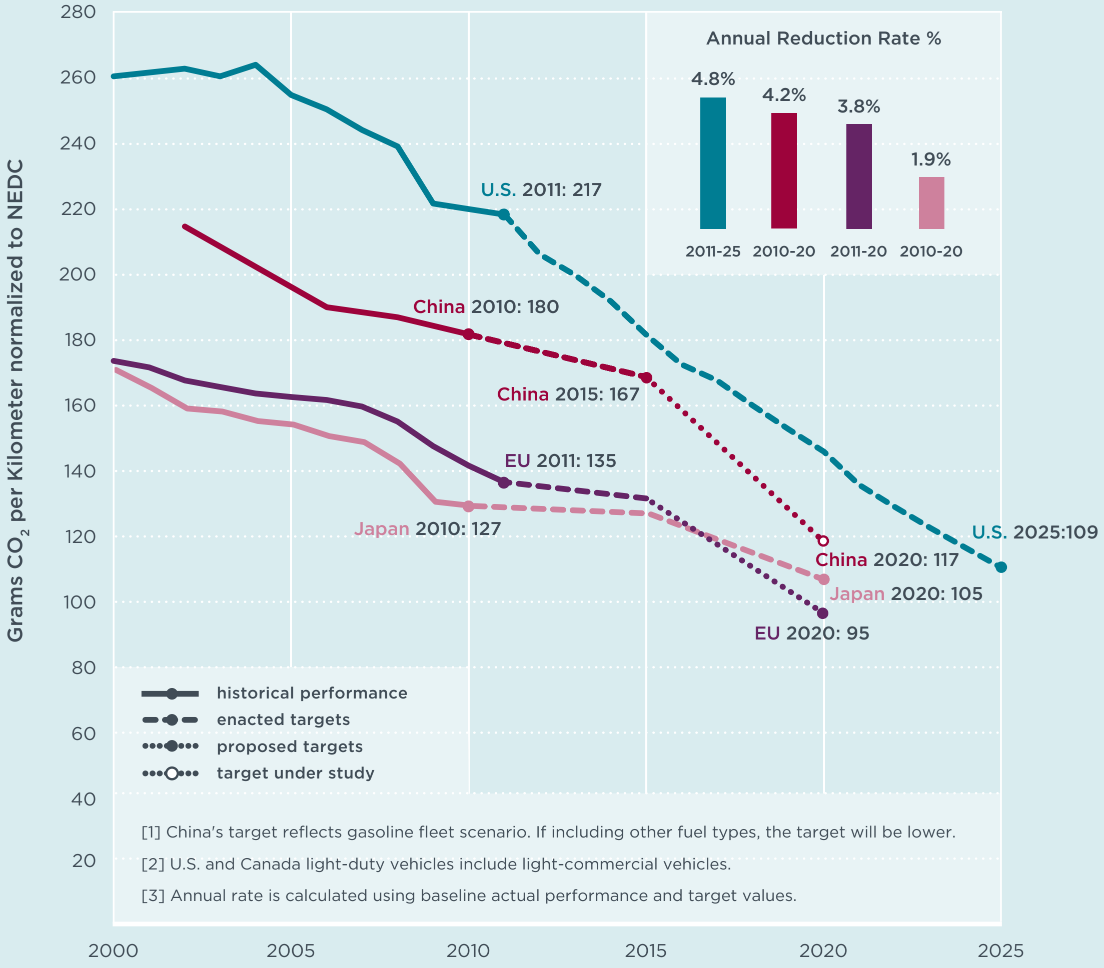

FIGURE 10. Annual Reduction Rate in LDV CO_2 Emission Rates

While the strength and impact of incentive measures vary widely, all regions evaluated in this report do have some form of existing fiscal incentives. Measures include taxes based directly on CO_2 or fuel consumption (EU-27, United States); taxes, incentives, and fees that vary with a vehicle attribute (e.g., engine size, vehicle weight) related to CO_2 emissions (EU-27, Brazil, China, India, and Japan); and targeted incentives to promote advanced-technology vehicles (United States, EU-27, India, Japan).[30] Because the impacts tend to be hard to separate from the baseline, this analysis does not consider the explicit effects of these fiscal incentives (except in Brazil).

Additional improvements, beyond adopted and pipeline policies, are both technically feasible and cost-effective in all regions. The *Potential* trajectory extends best-practice policy measures into all regions, applying a 4 percent annual rate of progress at the close of the regulated period or beginning in 2015 for the principal regions highlighted in this report (most of which have pipeline policies taking effect around this time) or in 2020 for the rest of regions. Technology assessments carried out in support of the U.S. 2025 standards, as well as longer-term efforts to project improvement in vehicle efficiency, support a doubling of vehicle fuel efficiency in a cost-effective manner between 2010 and 2030. Short-term fuel efficiency standards have focused on ensuring that the historically observed rate of improvement of 1–2 percent is directed toward reducing fuel consumption rather than merely improving vehicle performance. Efficiency regulations with longer lead times, such as the EU 2020 and U.S. 2025 LDV standards, have targeted 4–5 percent reduction in fuel consumption per year. Thus, a 4 percent reduction in fuel consumption is plausible through 2030, given the longer lead times, greater flexibility mechanisms to achieve compliance, and accelerated deployment of efficiency technologies.

Three limitations play a substantial role in bounding a government agency's regulatory ambition with respect to efficiency standards: (1) availability of technologies, (2) the need to consider how quickly technological advances pay consumers back, and (3) allowance for a phase-in period giving sufficient time for retooling of vehicle platforms and integration of new technologies. For LDVs, the ICCT has evaluated costs and benefits of a broad cross section of technologies that are expected to be available in the 2020–25 time frame.

CONTINUED IMPROVEMENT OF VEHICLE EFFICIENCY IS REQUIRED TO OFFSET THE EXPECTED GROWTH IN PASSENGER VEHICLE FLEETS AND ACTIVITY AROUND THE WORLD.

The analysis finds that extending the U.S. policy trajectory of a 4 percent reduction in fuel consumption to other major markets can be accomplished with existing and emerging technologies at a consumer payback of less than five years. As vehicle retooling is typically done every five years, a ten-year lead time and phase-in period would allow at least two retooling events for each model.[31, 32, 33, 34] Two- and three-wheeled vehicles tend to have much lower fuel consumption than cars, but still there is substantial room technically to improve further the efficiency of these vehicles. Because there is limited regulatory experience with fuel economy standards for motorcycles, this analysis chooses a lower-bound estimate for the policy potential of 1.1 percent per year. This is within the range estimate of near-term cost-effective emission reductions for the Indian vehicle fleet, of 5–10 percent by 2020 and 15–20 percent by 2025 or 2030.[35] The characteristics of two- and three-wheeled fleets vary widely, especially between regions in Asia and the vehicle populations in Europe and the United States. While vehicles outside of Asian markets are less likely to be inefficient two-strokes, the comparatively heavier, larger, and more expensive vehicles in other markets will have other areas of higher potential.

Figure 11 illustrates the emission benefits from adopted, pipeline, and potential LDV efficiency policies to 2030. Without fuel efficiency/GHG standards, passenger vehicle

CO_2 emissions and oil consumption could almost double between 2000 and 2030, with the fastest growth rates found in major new markets such as China, India, and Brazil. In essence, improvements in fuel efficiency will just offset the expected growth in passenger vehicle fleet and activity predicted around the world. The impact of strategies to reduce the number and frequency of trips could help reduce LDV emissions to 2000 levels. These strategies, including mode shift from LDVs to public transit and reduction of passenger activity through better land-use planning, are addressed in Chapter 6.

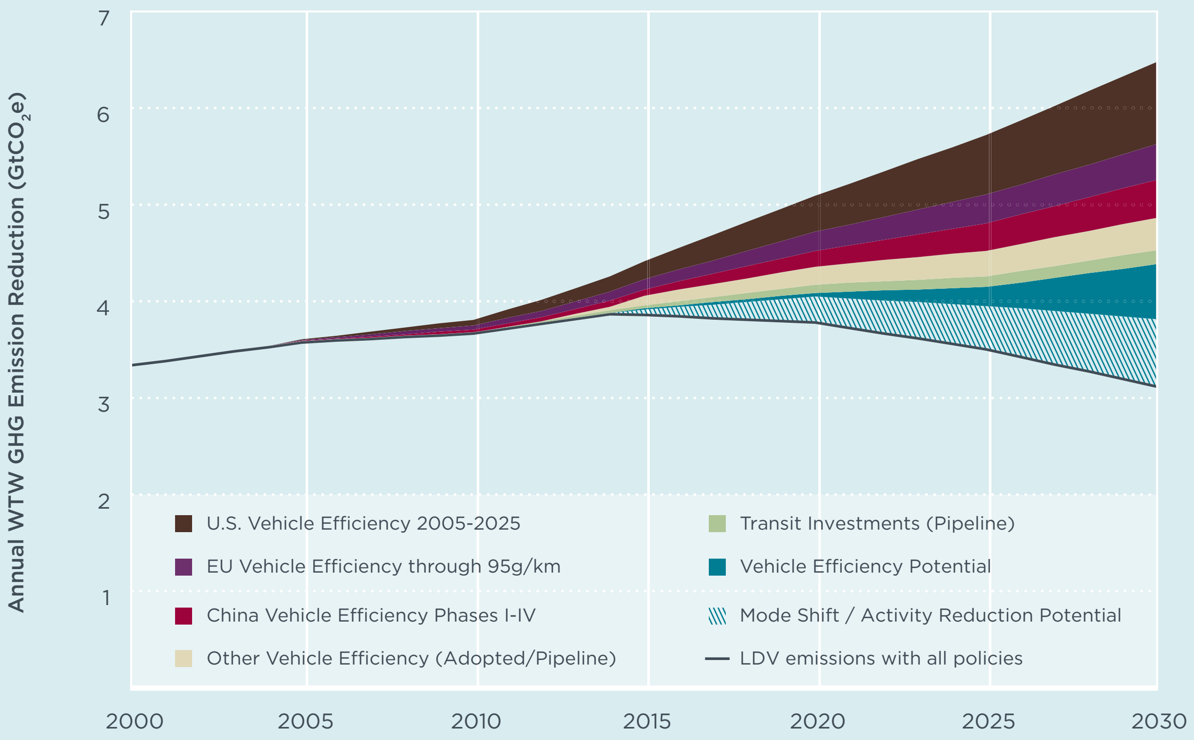

FIGURE 11. Policy Impacts on Global LDV Emissions

ELECTRIC-DRIVE VEHICLES

While vehicles powered by internal combustion engines are far from the limits of efficiency, meeting long-term emission reduction targets while activity continues to grow will require a switch to true low-carbon biofuels or electricity and hydrogen generated using renewable energy sources. Electric-drive technology—including plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs)—could provide substantial energy and GHG benefits over conventional technologies. Owing to low expectations for market share of electric-drive vehicles, limited near-term reductions of electrical grid carbon intensity, and the need to develop new hydrogen infrastructure for fuel cell vehicles, electric-drive vehicles are not expected to contribute substantially to GHG reductions by 2030. Sales of new electric-drive vehicles will need to ramp up substantially during this period in order to reduce technology costs and achieve wide-scale commercialization. Market commercialization will enable the transformation of the vehicle fleet to electric-drive technologies, which when coupled with grid decarbonization would achieve much more dramatic reductions in carbon emissions beyond 2030.

Many countries provide fiscal incentives for advanced-technology vehicles, including hybrids and a range of electric-drive vehicles. In this analysis, the effects of hybrid vehicles are accounted as part of manufacturers' strategy to meet national fuel efficiency and GHG standards and are thus incorporated into the efficiency metrics for LDVs. For this reason, the report does not focus in detail on energy consumption by fuel type or changes in the share of vehicle sales among conventional engine technologies. Furthermore, the analysis excludes fiscal incentives for other technology types because they are generally capped at low enough levels to be irrelevant.

Other policies that encourage the adoption of electric-drive vehicles are mandates, nonbinding goals or targets, and crediting systems as part of LDV standards. The United States, several countries in the EU-27 (e.g., Germany, the United Kingdom, France, Spain, Sweden), China, Japan, and South Korea have all adopted nonbinding goals or targets for PHEV and BEV sales. Because of the uncertainty regarding the effectiveness of nonbinding goals, targets, or fiscal incentives, this analysis excludes them from the *Adopted* or *Pipeline* trajectories. Crediting systems are already accounted for as part of national LDV standards, so they are not considered explicitly to avoid double counting. As a result, only zero-emission vehicle (ZEV) mandates are considered as part of the *Adopted* or *Pipeline* trajectories (Table 5).

TABLE 5. Summary of EV Policies

Region	Policy	
United States	**ADOPTED**	California ZEV mandate, 15% of new vehicle sales by 2025.
	PIPELINE	None
All Regions	**POTENTIAL**	Increasing growth in market share of electric-drive technologies, achieving a variable market share of ZEV LDV sales in 2030 ranging from 8–9% (United States, Japan, Canada, all of Europe, China, South Korea, and Australia) to 1–2% for all other regions. Market share for PHEV technologies ranging from 1–5%.

The growth in market share for electric-drive technologies out to 2030 was informed by an IEA report[36] and is consistent with other studies by the California Air Resources Board.[37] ICCT-supported modeling work under way suggests lower market shares for PHEVs than in the IEA report, as a result of higher costs associated with the double drivetrains required by these vehicles. At the same time, pure electric-drive vehicle costs, especially fuel cell vehicles, are expected to fall sharply. As a result, this analysis scales PHEV market shares, with the highest levels at 5 percent in the regions with biggest market share for advanced technologies.

There is a great deal of uncertainty about the technological evolution of electric-drive vehicles and the market's response to them. Recent modeling work supported by the ICCT suggests that if technological progress continues along the currently envisioned trajectory and public policies supportive of the electric-drive vehicles can continue well into the 2020s, then a sustainable transition to the electric-drive battery electric and fuel cell vehicles can take hold. Taking the uncertainty about technology, market behavior, and policy response into consideration suggests that a 20–60 percent market share for electric-drive vehicles by 2050 is plausible.[38, 39] In the time frame of this study (to 2030), electric-drive vehicles are expected to be mostly in the commercialization phase, with market share increasing rapidly as manufacturers are able to ramp up facilities for these new technologies toward the final years.

HEAVY-DUTY VEHICLES

Efficiency standards for HDVs—including both heavy-duty trucks and buses—are a relatively new area of policymaking. HDVs include many vehicle types and applications, ranging from heavy-duty pickup trucks and vans (Class 2b) to long-haul tractors (Class 8) and everything in between, from fire trucks, to buses, to straight trucks. Due to the tremendous range of vehicle types and applications, mandatory HDV regulations are complex, especially when compared to LDV regulations. The markets for these vehicles are much more geographically diverse than for LDVs. However, the industry is increasingly globalized and has expressed interest in regulatory alignment. There is a tremendous opportunity in the coming years—especially as many regions are working to develop regulatory proposals—to seek alignment between the regions, offering the potential for reduced costs for the manufacturers and increased benefits globally.

Table 6 describes the policies for heavy-duty vehicles (HDVs), which include heavy-duty trucks and buses, in each main region where policies have been adopted or are in the pipeline, followed by the assumptions for potential improvements within the specified time frame.

TABLE 6. Summary of HDV Efficiency Policies

Region	Policy	
United States	**ADOPTED**	MY 2014–18 HDV GHG and fuel efficiency standards for engines and vehicles, annual improvements of 1.3% and 4.2%, varying by weight class.[40] California: MY 2011+ new long-haul trucks and pre-2011 trailers and tires GHG regulation, efficiency improvements of 3–10% for all long-haul trucks entering the state.[41]
	PIPELINE	None
China	**ADOPTED**	Not modeled. Industry standard.
	PIPELINE	MY 2015 HDV standard, reducing new-vehicle fuel consumption by 10% in 2015 and 25% in 2020 from a 2010 baseline.
Japan	**ADOPTED**	MY 2015 HDV standards, 10–13% increase in fuel economy over 2002 baseline.
	PIPELINE	None
Canada	**ADOPTED**	None
	PIPELINE	MY 2014–2018 HDV GHG standards for engines and vehicles, harmonized with U.S. EPA.
Mexico	**ADOPTED**	None
	PIPELINE	MY 2014–2018 HDV standards harmonized with U.S. NHTSA, mandatory compliance beginning in 2016.
Main Regions	**POTENTIAL**	MY 2020–2030 (beginning at the close of the regulated time frame), 3.5% annual improvements for all classes of trucks and buses.
Other Regions	**POTENTIAL**	MY 2025–2030, 3.5% annual improvements for all classes of trucks and buses.

As can been seen in Table 6, far fewer countries currently have adopted or pipeline policies for HDVs than for LDVs. China's "industry standard" targeting the least efficient vehicle models is the only HDV regulation that has thus far come into implementation, and this analysis does not assume efficiency improvements because its effects are limited. Japan was the first country to adopt fuel economy standards for commercial trucks and buses in 2005, a standard that requires new MY2015 vehicles to have 10–13 percent higher fuel economy than the 2002 baseline. Many manufacturers have already met the 2015 standards as a result of fiscal incentives, and in 2011 approximately 60 percent of new-HDV sales complied with the 2015 standards, qualifying them for tax reductions. The adopted U.S. standards, with harmonization in the pipeline for Canada and Mexico, are the most comprehensive adopted HDV standards in the world. They fall far short, however, of the real potential for efficiency improvements within the regulatory time frame (2020).

Voluntary programs, such as EPA's SmartWay, have provided some of the essential building blocks for mandatory standards that have been adopted or are in the pipeline. SmartWay, a public-private partnership launched in 2004, works with freight and transportation carriers and vehicle manufacturers to improve supply-chain fuel efficiency. The SmartWay program has served as a model for similar programs in many regions around the world, including Europe, Mexico, and Guangdong, China. California's mandatory regulation, listed in Table 6, also builds off of the voluntary U.S. SmartWay program. The California program requires SmartWay-certified low rolling resistance tires and aerodynamic technologies for tractors and trailers to be installed on new and existing equipment and is the first in-use GHG regulation for HDVs in the world. California's regulation goes beyond federal HDV GHG/fuel economy standards by capturing aerodynamic improvements for new and in-use trailers and reductions in rolling resistance for new and in-use trailer tires. These additional requirements will reduce GHG emissions by 6 to 10 percent for long-haul tractor-trailers entering California, approximately 30 percent of all such trucks operating in the United States. Although not modeled in this analysis, the program serves as a regulatory example that can help to extend beyond and advance the benefits of new vehicle standards.

Many additional countries are considering and working toward HDV regulations, although they are not yet far enough along in the development of proposals to be listed in Table 6. A proposal for the second phase of the U.S. standards is anticipated in the 2013–15 period, and Canada would be expected to harmonize soon after, given its long history of aligning with U.S. standards. Europe has adopted standards for light commercial vehicles (LCVs) but nothing for heavier vehicles, which account for a larger share of oil consumption and emissions. The European Commission is, however, developing a strategy to reduce GHG emissions from HDVs, and a policy is expected sometime between 2018 and 2020. China's next phase of HDV standards is expected to have vehicle efficiency improvements similar to the U.S. rule, and due to the rapidly growing vehicle fleet in China, it will achieve the highest absolute emission reductions (Figure 12). South Korea is in the very early stages of developing HDV standards and is determining whether to model these standards after those in the United States or Japan. The Bureau of Energy Efficiency in India has stated informally that an HDV standard will be developed immediately following finalization of the LDV standard, and Brazil is expected to develop vehicle fleet efficiency measures for HDVs in the medium term under MDIC's Product Development Policy. Together, adopted and pipeline fuel efficiency standards for new HDVs are expected to generate annual reductions of 1.7 Mboe/day and 0.38 $GtCO_2e$ in 2030.

The stringency of initial regulatory efforts has been less ambitious than the potential would suggest. Considering policies beyond those adopted and in the pipeline, the *Potential* trajectory extends cost-effective and technically feasible measures into all regions, applying a 3.5 percent annual rate of progress starting in 2020 for the regions highlighted in this report and in 2025 for other regions. Studies by the National Academy of Sciences (NAS) and TIAX for the U.S. market have shown potential for fuel consumption reduction between 35 and 50 percent in the 2015–20 period as compared to model year 2008.[42,43] To adjust these estimates to a MY 2010 baseline (for the modeling purposes of this analysis), it is necessary to account for the increased efficiency provided by selective catalytic reduction (SCR) systems that were employed to achieve the nitrogen oxide (NO_x) levels required in the US2010 vehicle emission standards for local air pollutants. According to the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA), 2010 SCR systems are estimated to result in improved engine efficiency of approximately 3–5 percent compared to in-cylinder exhaust-gas-recirculation-based (EGR) emission systems.[44] Adjusting for SCR efficiency improvements, this analysis estimates that average fuel consumption reduction potential is approximately 45 percent for new combination tractor trucks and 40 percent across all other HDV categories by 2020.

For this analysis, a key challenge is estimating the fuel consumption reduction potential out to 2030, given the lack of comprehensive studies assessing the technical potential beyond 2020. Based on ICCT's best judgment, this analysis considers a further 25 percent reduction in fuel consumption between 2020 and 2030, such that the total potential from a 2010 baseline is roughly 55 percent for tractor trucks and 50 percent for all other HDV categories. Over a 20-year period from 2010 to 2030, the average annual reduction in fuel consumption is 3.9 percent for tractor trucks (the segment with the highest overall fuel consumption) and 3.4 percent for all other HDV categories. As a conservative estimate, this analysis assumes a 3.5 percent annual reduction in fuel consumption for all HDV categories. Because of the longer regulatory time frame associated with developing HDV regulations, new standards are assumed to take effect in 2020 for all the main regions (including those with regulations in place) and 2025 for other regions. As a result, these assumptions translate into potential fuel consumption reduction for new HDVs between 19 and 47 percent by 2030 from a 2010 baseline, depending on the region.

Although the 3.5 percent annual reduction in fuel consumption is based on U.S. studies, there is strong evidence that the same assumption can be reasonably used in other regions. Based on studies from TIAX and AEA-Ricardo for Europe, per vehicle technology potential for GHG reductions ranges from roughly 30 to 50 percent depending on the vehicle category, which is consistent with TIAX and NAS assessments for the United States.[45,46] Within North America, Canada and Mexico are both planning to implement HDV efficiency standards that align with the current U.S.

program, suggesting that alignment might continue in the next phase. Furthermore, the same manufacturers dominate across all three countries, with similar HDV configurations and operating patterns in each. Detailed technology potential studies have not been completed for developing markets such as China, Brazil, and India. One common aspect of these regions is that the technology used in the current baseline fleet is less sophisticated than in the United States and the European Union, allowing more scope for improvement in those fleets. Because estimates do not exist for other regions, this analysis assumes that the pace of annual reductions in fuel consumption rates in the United States and Europe is achievable for all regions, although the specific technology packages will be different, and later start dates will result in overall reductions that are not as great by 2030.

Although the assumed potential annual reductions in new-HDV fuel consumption are higher than what has been adopted to date and what is currently being discussed for policies in the pipeline, they are reasonable and cost-effective. Based on U.S. and European studies, HDV efficiency improvements in the 2015–20 interval, which are the basis of the assumptions for this analysis, typically have payback periods between one and four years depending on regulatory design, vehicle type, and region-specific activity patterns.

Figure 12 shows the effects of policies that have been adopted and those that are under development, along with potential policies to reduce HDV emissions. Adopted and pipeline policies are expected to reduce oil-equivalent consumption and GHG emissions by 1.7 Mboe/day and 0.38 $GtCO_2e$ in 2030, with an additional 3 Mboe/day and 0.6 $GtCO_2e$ from potential improvements in HDV efficiency.

Even assuming adopted and pipeline policies, HDV emissions are expected to grow substantially between 2010 and 2030, with the strongest growth in emerging markets such as India and China. Indeed, China’s HDVs are already responsible for 7 percent of global transportation sector GHG emissions (21 percent of the emissions from HDVs worldwide). By 2030, China’s HDVs are expected to account for 8 percent of total transportation sector GHG emissions, assuming adopted and pipeline policies. HDV emissions in India are currently less than half of levels in the United States but are predicted to grow nearly to U.S. levels in 2030. Under current policy expectations (adopted and pipeline), India’s and China’s HDVs are expected to account for 12 percent of global transportation sector emissions in 2030.

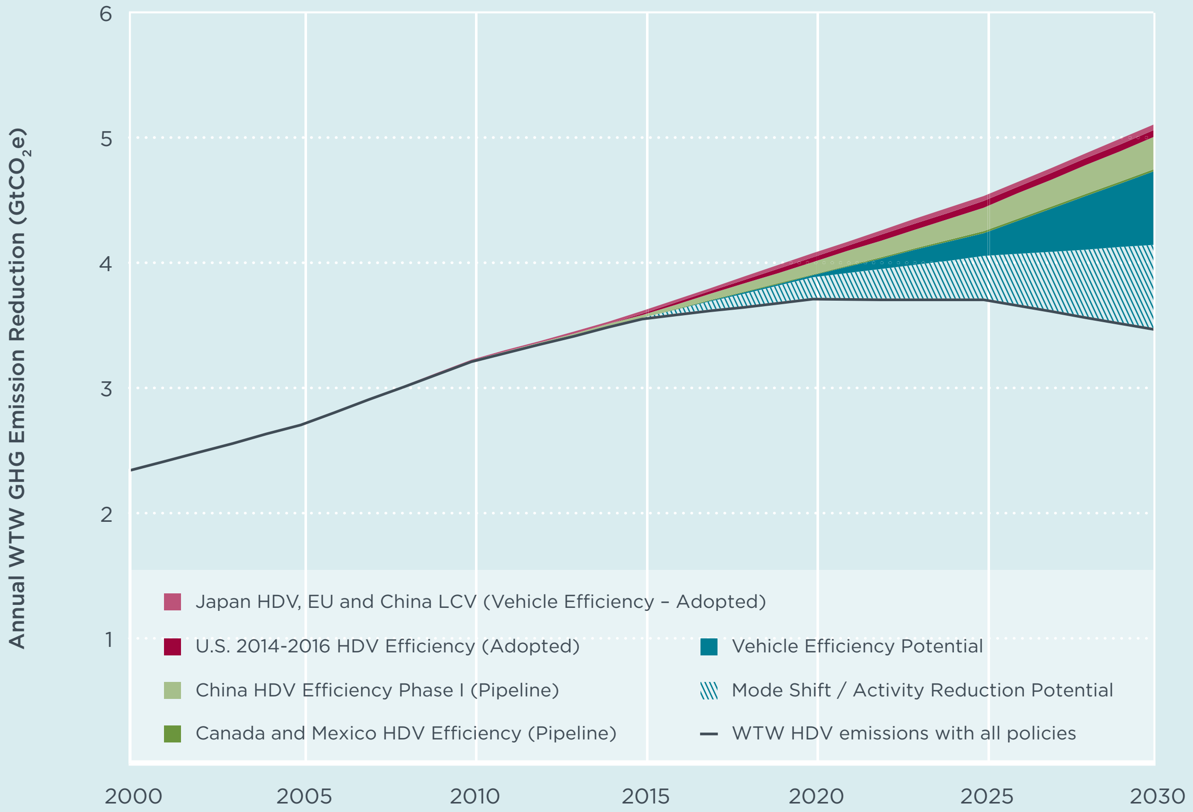

FIGURE 12. Policy Impacts On Global HDV Emissions

Unlike light-duty vehicle policies, which have already been in place for years, anticipated emission reductions from these upcoming policies are not sufficient to offset the projected doubling in global HDV emissions between 2010 and 2030 that would occur in the absence of these policies. As a result of the relatively long timeline for the launching of heavy-duty vehicle efficiency programs, the full benefits from near-term potential to improve HDV efficiency will not be realized until well after 2030. Programs such as California's long-haul truck regulation could help extend beyond and advance these benefits, which will continue to accrue past 2030 as new and more-efficient vehicles are incorporated into the fleet and zero-carbon technologies—not considered in this analysis for the heavy-duty sector—become cost-effective.

In the current analysis, potential HDV efficiency improvements could nearly stabilize emissions in 2020, while mode shift and activity reduction strategies (see Chapter 6) could begin to reduce absolute emissions in 2025. While efficiency potential is expected to continue to grow and account for a larger share of emissions beyond 2030, mode shift and activity reduction potential may grow at a slower rate in future years. More analysis is needed to assess fully the global potential to reduce emissions from freight transportation.

3. MARINE SECTOR

The marine sector represents an important and growing source of GHG emissions, accounting for about 6 percent of global oil consumption and 11 percent of global transportation GHG emissions in 2010, slightly less than total on-road emissions from Europe. Marine vessel fuel efficiency improved substantially until 2000, which was attributable to improvements in engine design and ship architecture. After 2000, high freight prices and dramatic growth in the maritime trade marginalized the importance of fuel costs, and ship efficiency improved very little over the following decade. As a consequence, the marine sector offers a tremendous opportunity for emission reduction.

Because a large share of marine activity crosses international borders and national authority to regulate it can be limited, the evaluation of policies to reduce marine emissions is primarily developed at the global level, with various countries collectively contributing. For the most part, the policy discussions to improve vessel efficiency have been held within the International Maritime Organization (IMO). Table 7 summarizes the policies considered in this analysis, divided into adopted, pipeline, and potential policies to ensure consistency with country policy assessments. Subsequent sections in this chapter provide details about each of these policies.

TABLE 7. Summary of Marine Policies

Region	Policy	
Global	**ADOPTED**	Regulation of new ship efficiency (EEDI): efficiency improvements of 5% in 2015, 15% in 2020, and 25% in 2025 for new vessels, relative to 2010 baseline.
	PIPELINE	Regulation of operational in-use ship efficiency: 67 $MtCO_2$ in 2030 (average of in-sector estimates from six IMO MBM proposals).
	POTENTIAL	Global MBMs (aggressive): 200 $MtCO_2$ in 2030 (upper-bound IMO estimate, which includes the 67 $MtCO_2$ considered in the pipeline). Improved operational efficiency: additional 50 $MtCO_2$ reduction in 2030.

Because the pipeline and potential emission reduction estimates are taken directly from another source (i.e., not calculated with the Global Transportation Roadmap model) that includes only fuel combustion emissions, this analysis builds in additional well-to-tank emission reductions to account for upstream processes. Total life-cycle emission reductions are shown in Figure 13.

ADOPTED POLICIES

The two major adopted policies considered in this analysis are the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). The EEDI is modeled as part of the *Adopted* trajectory, but the SEEMP is only included in the *Potential* trajectory because its associated reductions are not currently enforceable.

The EEDI regulation, passed in July 2011 by the IMO, will require new ships built after 2015 to be progressively more efficient than the average of ships of the same type built between 2000 and 2009.[32] The EEDI requires percentage increases in energy efficiency per capacity mile (i.e., ton-mile or TEU-mile) of goods transported relative to a reference average of ships for each type, size, and function. Specifically, the regulation will require large new ships (ranging from 5,000 to 20,000 deadweight tonnage depending on ship type) to be 10 percent more efficient beginning 2015, 20 percent more efficient by 2020, and 30 percent more efficient from 2025, with efficiency improvement ranges for smaller ships of 0–10 percent by 2015, 10–20 percent by 2020, and 20–30 percent by 2025. Individual flag administrators will be allowed to defer mandatory EEDI requirements for up to four years beyond the planned implementation dates. The EEDI applies to all new cargo ships greater than 400 gross tons, including oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers, and container ships. The EEDI formula for passenger ships, Roll-on Roll-off (Ro-Ro) passenger ships, and Ro-Ro cargo ships are still under discussion. Together, ship categories under the EEDI account for 72 percent of CO_2 emissions from the newly built fleet.[48]

The EEDI is a nonprescriptive, performance-based mechanism – it does not mandate which technologies should be used to comply with efficiency improvement targets. The most effective ways to attain the EEDI are to reduce ship power requirements (and thus speed) and enlarge ship capacity. Engine retuning may provide ships with a significant edge since it reduces power requirements exponentially compared with a ship with a similar size. In response, safety concerns have been raised, and minimum power requirements are under discussion.[49] The EEDI also has an adjustment factor for innovative technologies such as wind and solar power. The use of waste heat recovery will reduce the shaft generator/motor emissions and thus reduce the EEDI as well.[50]

Each new ship under the EEDI should carry the International Energy Efficiency Certification (IEEC). The IEEC is issued after the classification societies[f] verify all EEDI parameters during the first sea trial of new ships. The IEEC shows both the attained and required EEDI of the vessel. If a new ship does not comply with the EEDI after it enters force, the port state has the right to decline its entry into the port and fine the ship based on domestic regulations.

Although the EEDI allows individual countries to delay implementation for up to four years, the impact of this flexibility provision is expected to be minimal. Due to market conditions and industry business models, trends in shipbuilding are already moving toward efficiency improvements at levels that would satisfy early-tier EEDI requirements. For example, most major container companies are already planning to build larger and more efficient ships that will increase capacity amid fierce competition and high fuel prices. As a result, implementation delays are not expected. Taking into consideration the gentle reduction requirements for smaller ships, possible delays in implementing the EEDI in some flag states, and the exclusion of some ship types, this analysis assumes that new vessels become 5 percent more efficient by 2015 (from 2010 levels), 15 percent more efficient by 2020, and 25 percent by 2025 for the entire new fleet. The efficiency improvements under EEDI are estimated to reduce emissions in 2030 by approximately 200 $MtCO_2$.

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[f] A classification society establishes, maintains, and certifies the construction and operation of ships. Examples are the American Bureau of Shipping, Lloyds Register, Det Norske Veritas, and China Classification Society.

PIPELINE POLICIES

The main measures under active discussion to mitigate further marine GHG emissions involve a variety of options to increase the operational in-use efficiency of the marine fleet. Policies to promote the operational efficiency of the fleet are diverse, including modifications of the EEDI increasingly to include older in-use ships, regulations that make SEEMP measures more comprehensive and enforceable, and market-based mechanisms (MBMs) that harness pricing and market forces to influence ship activity more broadly. To investigate the full extent of such in-use ship efficiency possibilities, this analysis relies upon IMO assessments of in-use emission reductions that result from the various MBMs under consideration.[51] The six proposals range from fuel levies that would fund out-of-sector GHG reduction initiatives in developing countries to cap-and-trade systems that would raise and spend money entirely within the shipping sector based on the efficiency of new ships.[52]

The following table summarizes in- and out-of-sector GHG emission reductions in 2030 from the six proposals evaluated in this report. Emission Trading Schemes (ETS), the GHG Fund, the Port State Levy (PSL), and the Rebate Mechanism (RM) partly rely on out-of-sector offsetting. Other options, such as the Ship Efficiency and Credit Trading (SECT), emphasize in-sector GHG reductions through energy efficiency improvements. For the purposes of this report, only in-sector GHG reductions were considered, and given the wide range of estimates—from about 10 to more than 140 $MtCO_2$ in 2030—an average reduction of 67 $MtCO_2$ was considered. Appendix B provides further details about each of these proposals.

Proposals from each group have advantages and limitations. Proposals that result in large shares of the reduction stemming from out-of-sector offsetting may lead to substantial total GHG mitigation. They may also contribute to a climate fund that would lead to further GHG reduction. However, the quality of offsetting has been questioned. Additionally, an administration has to be authorized to collect and distribute the revenue, creating extra challenges. Conversely, the in-sector proposals will not have large administrative burdens, but the projected emission reduction is relatively small, and it lacks a metric to evaluate, enforce, and monitor improvements. As a result, this analysis only includes in-sector marine GHG mitigation.

TABLE 8. Summary of Marine MBM Proposals

Policy	Proposed by	2030 Reduction ($MtCO_2$)	
		In-Sector	Out-of-Sector
ETS Norway and France[g]	Norway, France	60	452
ETS UK	United Kingdom	60	452
GHG Fund	Cyprus, Denmark, the Marshall Islands, Nigeria, and the International Parcel Tankers Association	11	501
PSL	Jamaica	64	0
RM	International Union for Conservation of Nature and World Wide Fund for Nature	64	345
SECT[h]	United States	142	0
	Average	**67**	

POTENTIAL POLICIES

Beyond adopted policies and those in the pipeline, the marine sector has further emission reduction potential. The SEEMP establishes a mechanism for reducing fuel consumption through improvements in ship operational practices, preferably those that are linked to a broader corporate energy management policy. It will come into force in January 2013 upon issuance of the first IEEC, and failing to have a SEEMP on board could result in the denial of entry or a fine by the port state. The reduction potential of the SEEMP is hard to quantify, however, because it the SEEMP is not subject to approval or verification by a government entity; rather, it is reviewed and approved by the classification society (i.e., a nongovernment entity that establishes, maintains, and certifies the construction and operation of ships). As a result, this analysis classifies SEEMP as a potential initiative rather than an adopted one.

Like the EEDI, the SEEMP is a nonprescriptive regulation, providing shipping firms flexibility in meeting its strictures. For example, they can use weather routing, which helps shipping firms develop an optimum route for ocean voyages based on weather conditions. They can manage their speeds to avoid port congestion and reduce fuel consumption, a concept that is termed “virtual arrival.” They can also optimize the propeller inflow or clean the hull more frequently, both of which can reduce resistance during navigation.

In its current form, the SEEMP is not subject to verification, leading to great uncertainties regarding the level of emission reduction that could be achieved. There is an effort in the Marine Environment Protection Committee (MEPC) to strengthen the SEEMP and increase operational efficiency, calling for close monitoring from flag states and tying the IEEC with verification. For example, there were proposals at the MEPC 64 to put in place effective audit/monitoring systems, and remove market barriers that prevent the uptake of energy efficiency measures (i.e., split incentives mean that ship owners pay for installing energy-saving technologies, but charterers reap the benefits of fuel savings).[53]

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g These were originally two separate proposals, but their effects are essentially the same.

h Does not include non-MBM reductions from the mandatory EEDI (216 $MtCO_2$).

In addition, with fuel prices continuing to put pressure on freight rates and the bottom line, there is impetus within the industry to comply with the SEEMP and enhance energy management. In fact, speed reduction alone was responsible for about an 11 percent cut in CO_2 emissions in the past two years,[54] owing largely to surplus ships and plunging freight rates. Lower-carbon fuels have some potential to make an impact on the shipping sector: liquefied natural gas (LNG) has been suggested as a lower-carbon alternative (about 20 percent lower from a tank-to-wheel perspective). Thus far, uptake of LNG is mainly attributable to conventional pollutant standards for shipping—it meets the International Convention for the Prevention of Pollution from Ships (MARPOL) low-sulfur fuel standard and the stringent IMO Tier III NO_x standard—as well as its price advantage over marine gas oil. Other technologies that can achieve substantial reduction are being developed or becoming mature. Air lubrication, where compressed air is pumped to the bottom of the ship's hull to reduce the resistance, is expected to reduce CO_2 by more than 10 percent for most types of ships. Some maintenance measures that are often overlooked by ship owners are now re-emerging as effective approaches to reduce fuel consumption. Hull cleaning, for example, can remove biological growth and reduce frictional resistance, and polishing of propeller surfaces can reduce roughness and reduce accumulated organic materials; each is capable of achieving more than 5 percent CO_2 reduction fleetwide.[55]

Not only are energy-saving options widely available, they are also cost-effective. For example, the Institute of Marine Engineering, Science and Technology (IMarEST) identified more than 50 technologies and operational strategies that can be used to increase energy efficiency. Taking 22 of them for which the data are available, the IMarEST calculated that about a 450 $MtCO_2$ reduction can be achieved by 2020.[56] Of this, about 280 $MtCO_2$ can be reduced in a cost-effective manner. In a similar analysis, the Det Norske Veritas (DNV) included more technologies and alternative fuels and calculated that these could eliminate more than 800 $MtCO_2$ in 2030. More than half of this can be achieved with actual net cost savings.[57]

In light of this evidence, the IMO estimates the reduction potential of the SEEMP to be between 80 and 200 $MtCO_2$—this figure includes the market-based measures (in-use ship efficiency) considered to be in the pipeline. Assuming that stringent SEEMP verification is adopted, this analysis estimates that SEEMP may achieve an additional 50 $MtCO_2$ in 2030, placing the total SEEMP reduction potential between 130 and 250 $MtCO_2$ in 2030. Using the upper-bound estimate of 250 $MtCO_2$ for the analysis brings the total reduction (adopted policies like EEDI, pipeline measures such as MBM/in-use ship efficiency, and potential via improved SEEMP) to 450 $MtCO_2$ in 2030.

EFFECTS OF MARINE POLICIES

Figure 13 illustrates the emission reduction from different marine policies. Baseline marine GHG emissions are projected using current fleet CO_2 emissions and fleet growth factors described in the 2009 IMO Greenhouse Gas Study.[58] Under adopted policies, GHG emissions from marine sources are expected to swell from 2010 to 2030, equivalent to an increase of about 0.85 $GtCO_2$. The expected increase in marine emissions accounts for 17 percent of the total increase in global transportation GHG emissions from 2010 to 2030.

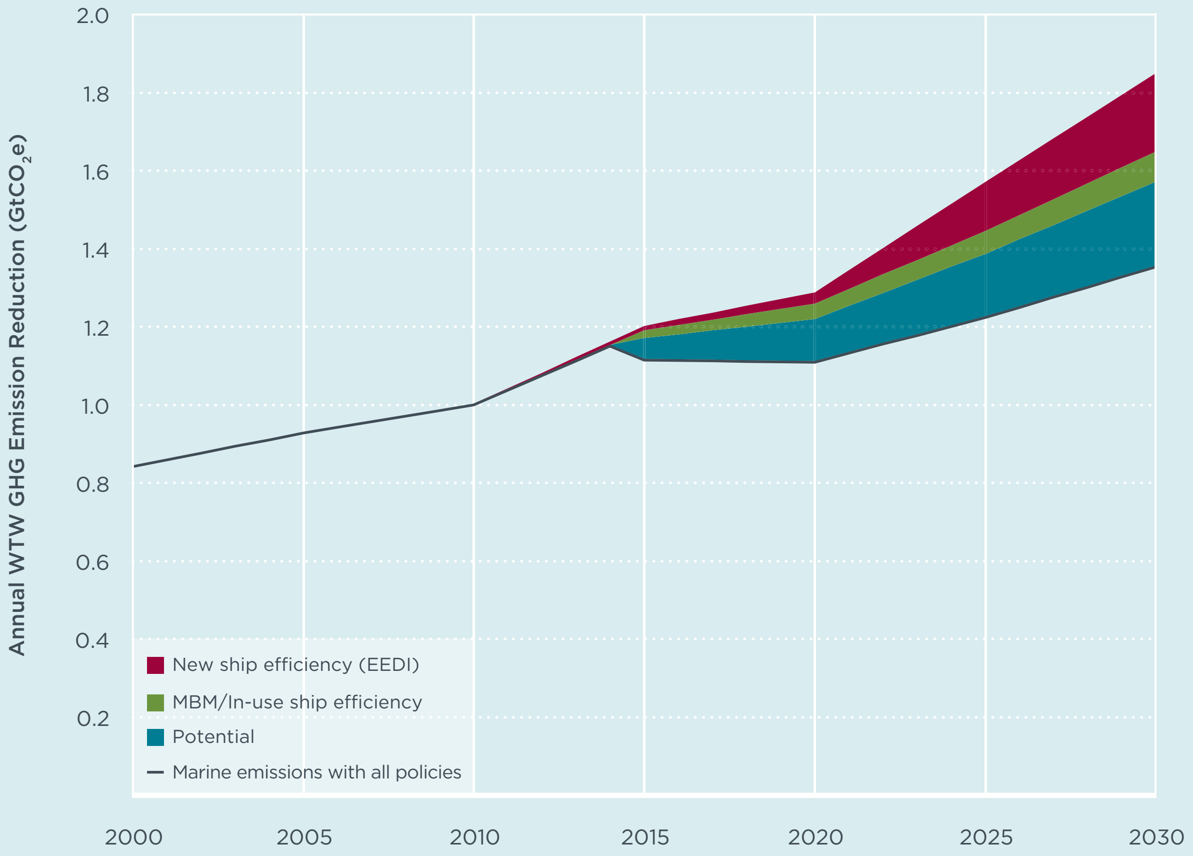

FIGURE 13. Policy Impacts on Global Marine Emissions

4. AVIATION SECTOR

Aviation accounted for about 9 percent of global transportation GHG emissions in 2010, and it is expected to have the highest rate of growth among transportation modes. GHG emissions from aviation will roughly double from 2010 to 2030, equivalent to an increase of about 0.9 $GtCO_2e$, which represents more than 18 percent of the increase in global GHG transportation emissions. Strategies to reduce aviation emissions are typically categorized according to four pillars: aircraft technology (through engine, aerodynamic, and structural improvements), aircraft activity (i.e., market-based measures, or MBMs), operations (through better air traffic control), and low-carbon fuels. Policy options to promote these strategies include CO_2 emission standards, taxes, levies, and emission trading schemes (ETS), support for technology research and development, and low-carbon fuel mandates and standards.

Since the aviation industry is fundamentally global in scale, with approximately 60 percent of fuel use occurring on international flights, the policy assessment for the aviation sector is developed at both the regional and global levels. The discussions of energy efficiency of new aircraft have been held mostly within the International Civil Aviation Organization (ICAO), while attempts to mitigate emissions growth from in-service aircraft are being led by the European Union (EU), which in 2012 began incorporating domestic and international flights into its regional cap-and-trade system for CO_2 emissions.

AIRCRAFT EFFICIENCY IMPROVEMENTS

Three main classes of technologies can help improve aircraft fuel efficiency: more-efficient engines, improved aerodynamics, and lightweight materials. Research indicates a trade-off between aircraft capability—payload capacity, range, and speed—and fuel efficiency. Modern aircraft are marketed with capabilities far beyond those typically used in service. For this reason, policies to promote a better match of aircraft to mission have significant potential to reduce emissions beyond that which technology alone can deliver. Finally, MBMs such as emission trading or fuel levies can contribute to climate protection goals by internalizing the cost of carbon and generating funds for either climate change mitigation or adaptation in vulnerable countries.

Contrary to conventional wisdom, rising fuel costs have not translated directly into increased fuel efficiency of new jet aircraft.[59] Improvements have been inconsistent over the past two decades, with fuel efficiency of new aircraft improving at an average of 0.3 percent per year from 2000 to 2010 on an available seat per kilometer basis due to a lack of new aircraft designs being brought to market. ICAO research suggests that the potential to improve new aircraft efficiency through 2030 is considerably higher. For example, in a 2010 technology review, ICAO estimated that the fuel efficiency of new aircraft designs with entry into service (EIS) dates of 2020 and 2030 could be improved by between 1.5 and 3.3 percent on an annual basis through 2030, relative to a typical aircraft delivered in 2010 and first certified in 2000 (Table 9).[60]

TABLE 9. Aircraft Fuel Efficiency Improvements by Technology Scenario[61]

EIS Year	Aircraft type	Annual % aircraft fuel efficiency improvements[*] relative to 2010		
		Business as Usual	Moderate pressure	Extreme pressure
2020	Single-aisle	2.6%	3.5%	←
	Small twin-aisle	2.1%	2.9%	←
2030	Single-aisle	1.7%	2.1%	3.3%[**]
	Small twin-aisle	1.5%	2.2%	2.7%

[∗] As evaluated on an R1 mission (100% maximum structural payload and maximum range at maximum payload).
[∗∗] Assumes open rotor engine architecture.

ICAO's CO$_2$ standard, under development and scheduled for a proposal in 2013, aims to reduce emissions by increasing the rate of efficiency improvement for new aircraft by promoting the development and deployment of more efficient engines, improved aerodynamics, and lightweight materials. The fuel efficiency estimates in Table 9 are for newly certified, "clean sheet" designs in 2020 and 2030 rather than the average new aircraft in that year. After accounting for the additional time needed for state-of-the-art technologies to diffuse to the average new aircraft, ICCT estimates that ICAO's standard can increase the rate of annual efficiency improvement for new aircraft by approximately one-third (i.e., 1.6 percent annual improvement compared to 1.2 percent since new aircraft designs are expected to be brought to market even in the absence of policies).[62] Reductions are expected to be magnified beyond the 2030 time horizon of this analysis because of the long operational lifetimes and slow turnover of commercial aircraft. The *Potential* trajectory assumes higher rates of annual improvement in aircraft efficiency (2.2 percent) between 2020 and 2030 than does the *Pipeline*; these rates are reasonable given ICAO's estimates that the average efficiency of new designs can be improved by 2.7–3.3 percent annually through 2030.

MARKET-BASED MEASURES

Over the long term, aviation demand typically increases between 4–5 percent annually, meaning that even with aggressive CO$_2$ standards emissions will continue to grow as demand outstrips efficiency improvements. For this reason, considerable attention has been paid to market-based measures to constrain or offset demand growth. In 2012, the EU became the first region to target aviation CO$_2$ emissions through demand management when it included domestic and international flights into its regional CO$_2$ cap-and-trade system—these measures are included as adopted policies and will eliminate an estimated 10 MtCO$_2$[i] within the sector in 2030. ICAO is also considering a global framework for MBMs (e.g., a global emission trading scheme), which would use an open cap-and-trade system or offsetting mechanism to internalize the cost of carbon and to raise funds for reductions in other sectors where such reductions might be less costly. Included in the *Pipeline* trajectory, these MBMs assume a 2.9 percent reduction in demand from higher ticket prices.[63] Additional emission reductions through out-of-sector mitigation are expected but not included in our analysis. The *Potential* trajectory assumes a global ETS with significantly higher carbon prices, reducing demand by almost 9 percent in 2030.

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[i] In the aviation section, CO$_2$ is the only GHG analyzed.

EFFECTS OF AVIATION POLICIES

Table 10 summarizes the aviation emission reduction measures modeled in this analysis. As shown, these policies incorporate aircraft technology (CO_2 standards) and economic instruments (market-based measures). Because of uncertainties regarding the carbon benefits and availability of biofuels, as well as the concern that the carbon intensity of fossil fuels will increase owing to higher use of unconventional fossil fuels, this analysis does not assume carbon savings from such fuels. Additional information concerning potential emission reductions from biofuels can be found in Chapter 5 and in Appendix C.

TABLE 10. Summary of Aviation Policies

Region	Policy	
EU-27	**ADOPTED**	EU ETS: MBMs (moderate). In-sector total reductions range from 0.7% in 2015 to 2.9% in 2030.
Global	**PIPELINE**	Global MBM equivalent in stringency to the EU ETS (moderate). ICAO CO_2 standard (moderate): 1.6% average annual improvements 2015–30.
	POTENTIAL	Global MBM (aggressive). In-sector total reductions range from 2% in 2010 to 8.7% in 2030. ICAO CO_2 standard (aggressive): 2.2% average annual improvements 2010–30.

As illustrated in Figure 14, global aviation emissions will increase to approximately 1.8 $GtCO_2$ in 2030 without additional policy action. ICAO's moderate CO_2 standard could reduce emissions by approximately 105 $MtCO_2$ in 2030, while a more aggressive CO_2 standard could cut 2030 emissions by an additional 50 $MtCO_2$. In terms of MBMs, the EU ETS will reduce in-sector emissions by approximately 20 $MtCO_2$ in 2030. Global MBMs with equivalent stringency could trim emissions by an additional 44 $MtCO_2$ in 2030, while more aggressive global MBMs could further bring down emissions by 107 $MtCO_2$ in 2030. Together, the policies modeled in this analysis could limit the increase in aviation GHG emissions to 1.5 $GtCO_2$ in 2030—a total reduction of 325 $MtCO_2$ from emissions in the reference trajectory. Given anticipated growth trends, substantial additional mitigation options would need to be considered in order to reduce or stabilize in-sector aviation emissions.

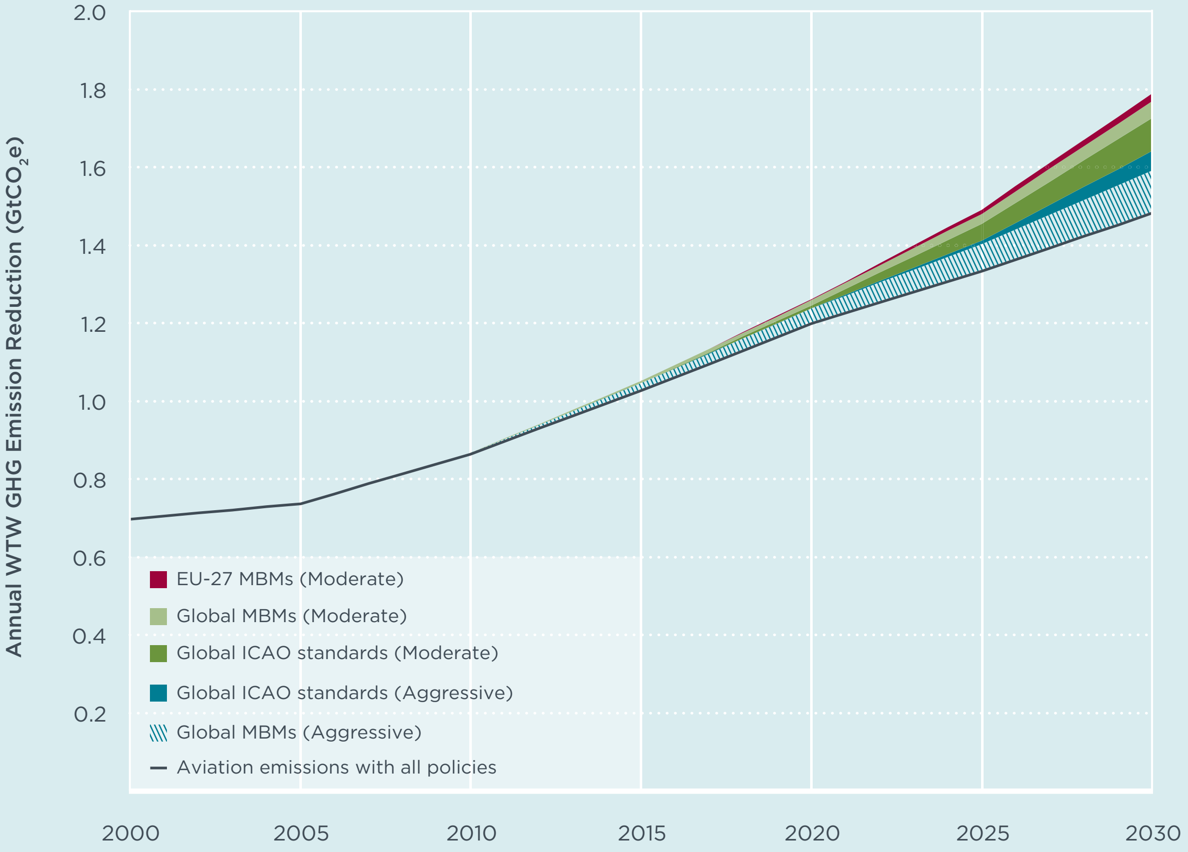

FIGURE 14. Policy Impacts on Global Aviation Emissions

5. FUELS

Reducing the carbon intensity of the energy used to power vehicles is a long-term priority for the transportation sector. Options that require a simultaneous shift in vehicle technologies and rollout of new fueling infrastructure, such as an increasing reliance on electricity coupled with grid electricity decarbonization or a shift to hydrogen-fueled vehicles and modes combined with low-carbon hydrogen production, have been accounted for in the vehicle category and, in order to avoid double counting, are not included in this chapter. Unfortunately, near-term policy options to reduce carbon from liquid transportation fuels have been hampered by the complexity of accurately measuring the carbon intensity of the fuels available. The life-cycle analysis of biofuels in particular has been subject to controversy and uncertainty.

While biofuel production has the potential to limit oil dependence, there is strong evidence that the liquid biofuels that have achieved the greatest market penetration to date will not deliver substantial net carbon savings compared to fossil fuels. In some cases, the use of biofuels is likely to increase net carbon emissions. Both the availability of biofuels in the future and the carbon benefits those fuels will deliver are unclear, and the biofuels for which the best environmental performance is generally claimed (e.g., ligno-cellulosic and algal biofuels) have the least certainty about time to commercialization and rate of deployment. There is not yet a consensus among regulators and scientists about the indirect emissions implications of biofuel production—in particular indirect land-use change—and there is uncertainty around issues such as the ‘fossil rebound’[j] and other indirect impacts.[k]

Many regions have implemented biofuel subsidies and mandates. These policies are intended to serve a variety of purposes, among them climate change mitigation, national energy security, and promotion of local agriculture. However, given a combination of legitimate concerns that crop-based biofuels can harm food security, a slower than anticipated commercialization of ‘advanced’ biofuel technologies, and disputes about the legality of some policies, it is difficult to assess with confidence how the market will develop within the time frame of this report. In particular, both the rate of biofuel deployment and likely overall emissions savings from three essential policies are currently uncertain:

1. In Europe, amendments to the Renewable Energy and Fuel Quality Directives are being discussed that would address indirect land-use change and aim to reduce competition between biofuels and food. These amendments could improve markedly the carbon performance of the policies but could simultaneously reduce the overall market size.[64]
2. In the United States, the Environmental Protection Agency has repeatedly had to reduce the mandate for the use of cellulosic biofuels under the Renewable Fuel Standard (RFS) because of limited availability. These fuels were expected to deliver the bulk of the carbon savings from the policy; however, there is some uncertainty that the 2022 targets will be met.

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[j] The expectation that adding one liter of biofuel supply to the market will only displace some fraction of a liter of fossil fuel use.

[k] Changes to agriculture could affect emissions sources such as livestock, fertilizer use, and rice paddies, while changing the uses of wastes and residues could have knock-on effects such as increasing demand for other fuels.

3. In California, the Air Resources Board's Low Carbon Fuel Standard has been challenged in the courts. In December 2011 a district judge ruled that the policy was in contravention of the dormant Commerce Clause of the U.S. Constitution, and while the ARB has been able to continue to enforce the policy pending appeal, the legal tussle has brought a great deal of uncertainty to the industry.

While there is much uncertainty about the immediate trajectory of the biofuels industry, in terms of both carbon savings and rate of deployment, there is no doubt that there are many potential opportunities to take advantage of currently underutilized resources to produce genuinely low carbon fuels. Targeting resources towards commercializing and scaling up these better pathways—while moving away from pathways that may be both ineffective for climate mitigation and negatively impact food security, biodiversity and the broader environment—will require careful management and regulation. Nevertheless, when biofuels can be done right, multiple benefits could be achieved, including substantial carbon savings, reductions in fossil fuel consumption and benefits to rural economies.

FUELS ASSUMPTIONS

As noted above, both the rate of deployment and carbon savings from biofuels are unclear in the period to 2030. Such savings as are delivered by genuinely low-carbon fuels are likely to be at least partly offset by predicted increases in the carbon intensity of fossil fuels. Between a lack of consensus in life-cycle analysis of basic fuels pathways, open questions about critical policies, and concern about the capacity of the market to deliver, there is currently a level of uncertainty around the carbon savings from biofuel policies that is much greater than uncertainties about the vehicle efficiency policies considered in this Roadmap. Rather than attempt to speculate on future outcomes based on insufficient evidence before the policy environment has settled, in general it is more appropriate for the near-term scope of this analysis not to assume substantial global emission reductions from biofuels.

An exception was made for Brazilian sugarcane ethanol because it is a well-established industry supplying a substantial fraction of Brazilian road transportation fuel demand and because the majority of technical studies support the conclusion that it can deliver meaningful carbon reductions even when indirect effects are accounted for. This analysis therefore assumes that Brazilian sugarcane ethanol has a direct emissions intensity of 15 gCO_2e/MJ—which is representative of the available life-cycle analyses—and an indirect land-use change emissions intensity of an additional 15 gCO_2e/MJ, based on modeling undertaken by the International Food Policy Research Institute for the European Commission. These assumptions yield a total emissions intensity of 30 gCO_2e/MJ, about one-third that of fossil-fuel-derived gasoline.

Brazil has a government-mandated ethanol blend in gasoline fuel, which has ranged from 18 to 25 percent. There is also extensive use of higher ethanol blends and high market penetration of flex-fuel vehicles (as well as a legacy fleet of ethanol-only vehicles). In response to an ethanol shortage in early 2011, the government created new rules defining ethanol as a fuel (as opposed to an agricultural commodity) and thus authorized the Petroleum National Agency (ANP) to regulate and control its production and distribution. Because of historical support for ethanol and the official authority of the government to control future production and distribution, this analysis regards the increasing share of ethanol use (about 40 percent in 2000, increasing to about 50 percent in 2010) as an adopted policy. Brazil's national on-road emission inventory targets future increases in the share of ethanol until 2020 (about 65 percent), and the analysis assumes this increased use as a pipeline policy.[65]

This analysis does not assume further GHG benefits from biofuels in the *Potential* trajectory. There is certainly potential in principle for GHG reduction through the use of biofuels. However, there is a critical difference between how biofuel *could* be produced sustainably and how biofuel *would* actually be produced if and when expansion is driven by policies or the market. Reductions that would be realized in practice would depend heavily on feedstock choice and land-use regulation. For example, it is possible that, in the absence of stricter controls on global land use, biodiesel produced from vegetable oils could have equal or higher carbon intensity than diesel.[66] Land-use change is not an issue only for food-based fuels but for any cropping system that competes for fertile agricultural land—there is simply not enough confidence about the likely volumes of future biofuel supply and the carbon intensity of such fuels to assess their potential for yielding near-term emission reductions.

Although this analysis does not assume any near-term promise for GHG savings from biofuels, there are several studies led by influential international agencies, governments, and academics that argue for significant technical potential for fuel production and carbon savings from biomass. A more detailed discussion of these studies is provided in Appendix C.

HIGH-CARBON FUELS

In addition to uncertainty regarding the carbon benefits and deployment of biofuels, there is an expectation that the average carbon intensity of fossil fuels could increase thanks to growth in the carbon-intensive extraction and refining of unconventional fossil fuels. According to the IEA (2011), unconventional resources are expected to account for close to 7 percent of world oil production by 2030. In general, unconventional oil investment and production is dependent on relatively high oil prices since these resources tend to have higher production costs than most current oil extraction. Efficiency measures can act to reduce oil demand, thereby decreasing price drivers for oil extraction.

While an increase in high-carbon fuels is not included in this analysis, Figure 15 compares the effects of increases in unconventional oil with those from efficiency policies in all transportation modes. This sensitivity analysis assumes IEA's forecast of a 7 percent share of high-carbon fuels in world oil production in 2030, and it presupposes that high-carbon fuels have a CO_2 content (in gCO_2/MJ) that is 10–30 percent higher than conventional fuels. While global emission savings of about 17 percent in 2030 can be expected from adopted and pipeline policies, increased use of high-carbon fuels could increase 2030 transportation emissions by 1–2 percent.

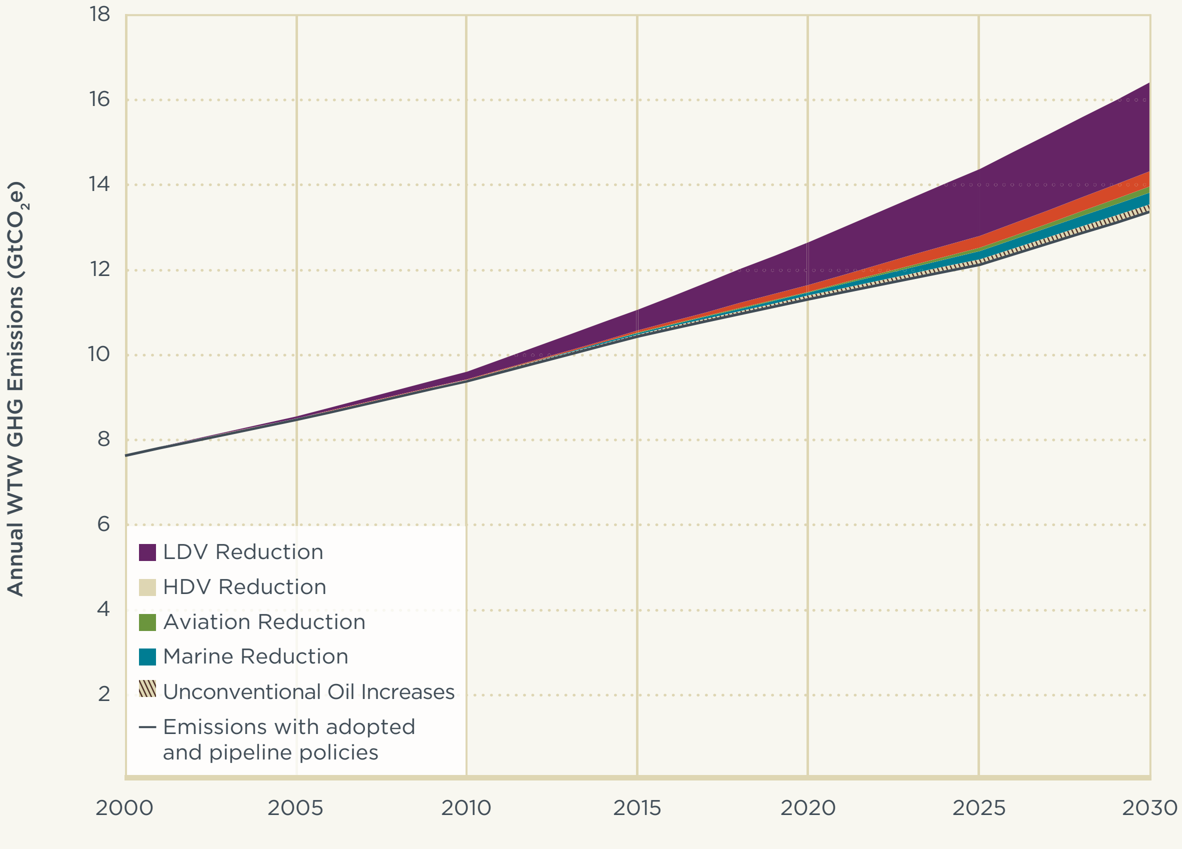

FIGURE 15. Effects of High-Carbon Fuels on Global GHG Emissions

6. MODE SHIFT AND ACTIVITY REDUCTION

Growth in activity is the primary driver for increasing transportation emissions and fuel consumption. Improvements in vehicles and fuels alone will not be enough to reverse the trends in emissions growth, and additional measures to shift people and goods to less energy-intensive modes and to slow the pace of expansion in vehicle activity are needed to meet long-term climate goals. There have been some indications that passenger activity patterns may be changing; for example, car ownership rates among young adults are dropping in Europe. However, it is still too early to discern new trends.[67] Such hints, along with the growing number of policies and programs around the world that reduce private on-road vehicle use, suggest that there is near-term potential to invest in policies and infrastructure that can support further activity reduction and mode shifts. While this analysis is far from exhaustive, ICCT has partnered with the Institute for Transportation and Development Policy (ITDP) to model some of the policies available to achieve emission reductions through mode shift and activity reduction.

There are numerous policy interventions that can redirect growth in passenger vehicle and truck activity to public transportation, nonmotorized transportation (NMT), and rail and reduce overall vehicle activity. Fiscal and policy measures intended to *push* drivers away from private vehicles, include road use pricing, congestion charging schemes, on-street parking pricing, parking restrictions, and strategies such as fuel or carbon taxes. Wider mobility options, which can *pull* drivers away from private vehicles, can be achieved through transportation infrastructure improvements and investments. These policies also rely on the implementation of integrated transportation networks and land-use planning. Mobility options include the implementation of bus rapid transit (BRT), passenger and freight rail systems, ride-sharing schemes, and bike-sharing systems. Examples of these strategies are included in Appendix D.

Table 11 summarizes the policies and strategies for mode shift and activity reduction in each policy trajectory. Fiscal and other policy measures are expected to be an integral part of achieving the potential analyzed, in combination with investments in public transit and and freight rail infrastructure, policies targeting urban land-use planning, and improvements in freight logistics. It will take a comprehensive suite of policies, with both push and pull strategies working together, to achieve the full potential for reductions in passenger and heavy-duty vehicle activity and shifts of passenger and freight transportation to less carbon-intensive modes.

IMPROVEMENTS IN VEHICLES AND FUELS ALONE WILL NOT BE ENOUGH TO REVERSE THE TRENDS IN EMISSIONS GROWTH, AND ADDITIONAL MEASURES TO SHIFT PEOPLE AND GOODS TO LESS ENERGY-INTENSIVE MODES AND TO SLOW THE PACE OF EXPANSION IN VEHICLE ACTIVITY ARE NEEDED TO MEET LONG-TERM CLIMATE GOALS.

TABLE 11. Summary of Mode Shift and Activity Reduction Policies

	Mode Shift*					Activity Reduction	
	BRT	Other Bus	NMT	Passenger Rail	Freight Rail	Urban Land Use	Logistics Improvements
United States	🟢🔵	🟢🔵	🔵	🟢🔵	🔵	🔵	🔵
EU-27	🟢🔵	🟢🔵	🔵	🟢🔵	🔵	🔵	🔵
China	🟢🔵	🟢🔵	🔵	🟢🔵	🔵	🔵	🔵
India	🟢🔵	🟢🔵	🔵	🟢🔵	🔵	🔵	🔵
Japan	🟢🔵	🟢🔵	🔵	🔵	🔵	🔵	🔵
Brazil	🟢🔵	🟢🔵	🔵	🟢🔵	🔵	🔵	🔵
Canada	🟢🔵	🟢🔵	🔵	🔵	🔵	🔵	🔵
South Korea	🟢🔵	🔵	🔵	🟢🔵	🔵	🔵	🔵
Mexico	🟢🔵	🔵	🔵	🟢🔵	🔵	🔵	🔵
Australia	🟢🔵	🔵	🔵	🟢🔵	🔵	🔵	🔵

🟢 Pipeline 🔵 Potential *Adopted mode shifts policies included in *Pipeline.*

ADOPTED AND PIPELINE POLICIES

ITDP undertook a project-by-project analysis to estimate the emission reductions of major public transportation projects, fully or partially funded, that are under way around the world. The analysis includes more than 100 projects in the main regions highlighted in this report, and it is the basis of the strategies contained in the *Pipeline.* For each transit project, the analysis considers the added capacity (in passengers/day), average trip length, and assumed level of activity shifted from private automobiles. Because of difficulties in separating out historical benefits, this analysis groups the impacts of all projects—even those begun or completed in the last decade—into the *Pipeline* trajectory. Owing to a lack of data regarding freight rail projects, shifts from trucks to freight rail are considered only in the *Potential* trajectory. Activity reduction is also only contemplated in the analysis of potential policies, likewise due primarily to a lack of data. Table 12 summarizes the shifts from LDVs to public transit estimated in the project-by-project analysis.

TABLE 12. Passenger Mode Shifts (Adopted and Pipeline)

Region	Share of LDV Vehicle-Kilometers Traveled (VKT) Shifted							
	To Bus				To Rail			
	2015	2020	2025	2030	2015	2020	2025	2030
United States	1.1%	2.1%	2.4%	2.7%	0.0%	0.0%	0.0%	0.0%
EU-27	1.1%	2.2%	2.5%	2.9%	0.0%	0.1%	0.1%	0.1%
China	0.2%	3.1%	4.3%	5.5%	0.0%	2.6%	2.6%	2.6%
India	0.6%	3.0%	5.1%	7.3%	0.0%	2.1%	2.1%	2.1%
Japan	0.1%	0.1%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%
Brazil	0.2%	0.8%	2.0%	3.1%	1.2%	1.7%	1.7%	1.7%
Canada	0.1%	0.1%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%
South Korea	0.1%	0.1%	0.5%	1.0%	2.0%	2.0%	2.0%	2.0%
Mexico	0.1%	1.9%	5.7%	9.5%	0.1%	0.1%	1.0%	2.0%
Australia	0.0%	0.0%	0.9%	1.8%	0.0%	0.1%	0.1%	0.1%
Other Regions	-	-	-	-	-	-	-	-

POTENTIAL POLICIES

The assumptions made in the *Potential* trajectory are divided into passenger and freight modes. There are multiple policy options and designs that could be incorporated to meet the full policy potential in any country or region, although it is likely that both push and pull strategies would be needed to achieve the full potential. The decision to choose one path or another depends on many characteristics that vary from country to country, such as different levels of tolerance for and interest in incentives, taxation, and regulation. The descriptions below provide the basis for our assessment but do not seek to prescribe a specific policy pathway.

Mode shift strategies include policy suites to shift travel to less energy-intensive modes, from private automobiles to public transit and NMT (i.e., pedestrians and bicycles) and from heavy-duty trucks to freight rail. These shifts are to be accomplished by infrastructure investments and improvements in mass transit and NMT amenities, in combination with fiscal measures and other traffic demand management strategies that reduce automobile dependence and prioritize low-carbon transportation. For freight movements, infrastructure investments as well as fiscal and economic incentives encourage freight rail as a viable option to shipments currently moved by trucks.

PASSENGER MODE SHIFT POTENTIAL ASSUMPTIONS

The assumptions of mode shift potential are based on the project-by-project analysis of major transit investments, resulting in transfers from passenger vehicle activity to bus and rail. In that analysis, Mexico stood out as the country for which the most complete information on transportation investments was available. As a result of the extensive investments being made there, Mexico was on track to maintain the 2010 modal split of transit and passenger car activity rather than increasing the share for passenger cars, as was expected to occur in all other high-transit-share regions (see Figure 16). In order to develop the activity potential, the analysis assumed that, through a combination of policies to make private vehicles less desirable, possibly including parking policies, car use restrictions, and fiscal measures, as well as additional investments in transportation infrastructure, Mexico could double its diversion from passenger vehicles to public transit to achieve a shift of approximately 20 percent from baseline activity.

To bring other regions up to a similar level of mode shift, their project-by-project shifts had to be tripled rather than doubled. In essence, this analysis assumes that mode shift potential is directly linked to current developments in transit investments and that in all regions these could be expanded and accelerated in combination with other policy measures not analyzed here. For those regions not highlighted in this analysis, the assumed potential is the median percentage shift in LDV activity among the regions evaluated in the project-by-project analysis. In most developing countries even this level of mode shift from baseline activity will only serve to slow the growth in passenger vehicle mode share, while in developed countries it might actually reduce the mode share for passenger vehicles. The effects of potential mode shifts are discussed below.

TABLE 13. Passenger Mode Shift Assumptions (Potential)

Region	Share of LDV VKT Shifted							
	To Bus				To Rail			
	2015	2020	2025	2030	2015	2020	2025	2030
United States	1.1%	4.3%	6.1%	8.2%	0.0%	0.0%	0.0%	0.1%
EU-27	1.1%	4.3%	6.3%	8.6%	0.0%	0.3%	0.3%	0.4%
China	0.2%	6.2%	10.8%	16.5%	0.0%	5.2%	6.6%	7.9%
India	0.6%	6.1%	12.8%	21.8%	0.0%	4.3%	5.3%	6.4%
Japan	0.1%	0.3%	0.4%	0.5%	0.0%	0.0%	0.0%	0.0%
Brazil	0.2%	1.7%	4.9%	9.2%	1.2%	3.5%	4.3%	5.2%
Canada	0.1%	0.3%	0.4%	0.6%	0.0%	0.0%	0.0%	0.0%
South Korea	0.1%	0.1%	1.3%	3.0%	2.0%	4.0%	5.0%	6.0%
Mexico	0.1%	3.8%	11.4%	19.0%	0.1%	0.2%	2.1%	3.9%
Australia	0.0%	0.1%	2.3%	5.5%	0.0%	0.2%	0.3%	0.4%
Other Regions	0.2%	2.7%	5.5%	8.4%	0.0%	0.3%	1.5%	2.8%

The accuracy of any global analysis of national transportation mode shares is inherently limited by the availability of reliable data since the level of data collection, survey methods, and even definitions differ substantially across regions. Specifically, data for the overall level and share of nonmotorized transportation is scarce, especially in developing economies. The lack of consistent national data on NMT activity constrains the modeling capacity of the Roadmap model; specifically, most cities and regions define and measure NMT activity as the share of trips rather than the share of passenger-kilometers. Since NMT trips tend to have much lower average distances than passenger vehicle trips, even a high NMT trip share translates to a lower share of total passenger-km. While the Roadmap model framework allows for shifts from LDVs to NMT, the lack of robust, globally consistent activity data precludes this analysis from making refined assumptions about potential diversion to NMT in each region. Instead, the analysis includes a conservative placeholder assumption that 1 percent of LDV activity could shift to NMT in 2015, scaling up to 4 percent of baseline LDV activity in 2030.

Cities and regions around the world—Mexico City, New York, Berlin, Hangzhou, to name a few—are making a concerted effort to increase bicycle and pedestrian infrastructure, including public bike-sharing programs, pedestrian malls, and taking over road space for bicycle and pedestrian uses. The placeholder included here is intended to recognize the importance of both near-term policies that can encourage movement to NMT (e.g., bicycle and pedestrian infrastructure investments, congestion and parking pricing, etc.), as well as long-term changes in land use, network connectivity, and urban density.

FREIGHT MODE SHIFT POTENTIAL ASSUMPTIONS

Because of a lack of data on current and planned freight rail investments, the potential for mode shifts differs by region based on the level of existing freight rail activity (Table 14). Regions with extensive freight rail infrastructure are assumed to have “moderate” potential increases in rail activity (in percentage terms, starting from a larger baseline), whereas regions with relatively little freight rail infrastructure are assumed to have the potential for “aggressive” percentage increases in freight rail (with a lower overall impact because they are starting from a smaller baseline). It is presumed that increases in freight rail activity (above those estimated without policies in place) are associated with shifts from long-distance trucking, which would rely on policies to push freight away from trucking (e.g., truck user fees) in addition to freight rail investments. Various studies have estimated that the maximum theoretical increase in freight rail activity in the EU is 90–100 percent by 2030.[68,69] The values used in this sensitivity analysis assume that slightly less than half of this theoretical potential (40 percent) is achieved in countries with “aggressive” potential, while countries with “moderate” potential realize half that level of mode shift. We expect that a great deal of this shift could be accomplished through optimization of current freight rail infrastructure and fiscal policies that shift the incentive away from road transportation rather than the development of additional rail lines. However, to account for policy and infrastructure development timelines, increases in freight rail activity are scaled up over time to reach these potentials by 2030. For those regions not highlighted in this analysis, the assumed potential is the median percentage increase in freight rail activity among the regions evaluated here.

TABLE 14. Freight Mode Shift Assumptions (Potential)

Level of Shift	Region	Increase in Freight Rail Activity			
		2015	2020	2025	2030
Moderate	United States, China, Japan, Canada, South Korea, Australia	0%	5%	10%	20%
Aggressive	EU-27, India, Brazil, Mexico	0%	10%	20%	40%

Many countries also have targets in place to diminish production of coal-fired electricity. As coal transportation tends to monopolize lower-carbon-intensity modes, such as rail and short-sea shipping, such reductions could open up more potential for freight mode shift without development of additional rail or port facilities or optimization of current infrastructure.

ACTIVITY REDUCTION POTENTIAL ASSUMPTIONS

Land-use planning regulations that encourage compact cities and neighborhoods can be coupled with travel demand management policies (e.g., parking restrictions, congestion pricing) to reduce overall passenger transportation activity. Four cities in China (Shanghai, Beijing, Guiyang, and now Guangzhou) have taken steps to limit the number of private vehicle registrations, a policy that will certainly restrict passenger vehicle activity in those areas.[55] This analysis assumes that combined land-use planning regulations and TDM policies, including fiscal measures and parking policies to discourage urban car use, could reduce urban passenger vehicle activity or shorten average urban trip distances by 2 percent in 2020, increasing to 5 percent in 2030 (Table 15).

For freight, policies such as fiscal measures and road use pricing can be implemented to incentivize logistics improvements that lower freight activity. Road user charging for heavy trucks in Europe, now in place in Switzerland, Germany, and

Austria, provides one clear policy example. In Switzerland, where truck traffic had been growing at a rate of 7 percent per year, vehicle activity declined about 10 percent overall from 2000 to 2007, while the tonnage transported increased by 5 percent.[71,72] Switzerland has also used the proceeds from this charge partially to fund an ambitious freight rail project. This analysis assumes that logistics improvements could reduce overall freight activity (trucking and freight rail) by 3 percent in 2020 and 5 percent in 2030. Appendix D provides an overview of other policy options to reduce transportation activity.

TABLE 15. Activity Reduction Assumptions (Potential)

Policy	Reduction in Transportation Activity			
	2015	2020	2025	2030
Reduction of average urban trip length	0%	2%	3%	5%
Logistics improvements	0%	3%	3%	5%

Future analyses can refine the assumptions about the potential for logistics improvements as information and communication technologies combine with modernization of the trucking and freight sector across much of the world. For example, China and India, with large fleets of monobody trucks with low load factors, have a huge potential to boost system efficiency by combining drop-and-hook tractor-trailer systems with better logistics support. Additional analyses can examine reductions in average trip length as a result of new urbanization and urban redevelopment expected to occur in each region.

EFFECTS OF MODE SHIFT AND ACTIVITY REDUCTION POLICIES

The quantification of the decline in emissions from mode shift and activity reduction policies and strategies is difficult. Poor data quality on mode shares and challenges in establishing clear relationships between a given policy or investment and its effects on mode shift and activity reduction limit our ability to determine accurately the emission consequences of these strategies. The fact that most of the aforementioned policies are typically implemented at the local or regional level also creates challenges in scaling them up to the national level. In the face of such uncertainty and a lack of data that precludes the use of more fully specified activity modeling, this analysis excludes several strategies from its assessment of the emission reduction potential of mode shift and activity reduction policies. Not included are the effects of improved traffic flows due to reduced congestion on in-use vehicle efficiency and the effects of more-comprehensive activity reduction through better urban planning and widespread application of information, communication, and pricing strategies to manage and balance the supply and demand of transportation.

In this analysis, mode share is defined as the share of national motorized transportation activity, measured in passenger-kilometers and ton-kilometers, by a particular mode. Given the data limitations described previously, specific mode shares in the following two figures are best if used for directional purposes. These figures illustrate the share of public transit and freight rail in 2010 (gray dots) and in 2030 assuming no policies (yellow dots), adopted and pipeline policies (green dots), and potential policies (blue dots).

FIGURE 16. Public Transit Mode Shares

There is wide variation in the share of public transit across nations, with developing countries—in particular those in Asia—relying heavily on transit use and developed countries leaning toward more automobile dependency, especially in North America and Australia. Without active policies in place, the share of public transit will decline in all countries from 2010 to 2030; the fastest changes are expected in developing countries, where high rates of economic growth coupled with low initial vehicle activity stimulate rapid shifts toward private automobiles. Adopted policies and those in the pipeline are not sufficient to maintain or increase transit use—with the exception of Mexico, which has invested heavily in BRT and continues to plan for the expansion of existing systems and dissemination to additional cities.

With respect to freight movements, China, the United States, Canada, and Australia have the highest shares of freight rail given the large distances needed to cover to link various places, the predominance of bulk (and heavier) commodities, and the historical investment in freight rail infrastructure. Some countries such as those in Europe and Japan have much lower shares of freight rail given their shorter distances and a rail system that is mostly dedicated to passenger transportation. Freight rail shares in North America, Australia, Brazil, Japan, and South Korea are expected to remain relatively unchanged between 2010 and 2030 in the absence of policies, and policies in the pipeline are not expected to change these trends. China and India are expected to have sizable reductions in freight rail shares between 2010 and 2030—these shifts amount to more than 10 percentage points; however, potential transit investments could offset roughly half this reduction in China and a substantial share of it in India. Trends in the EU-27 also indicate reductions in freight rail shares without active policies; however, potential transit investments could increase the share of freight rail in 2030 relative to its share in 2010.

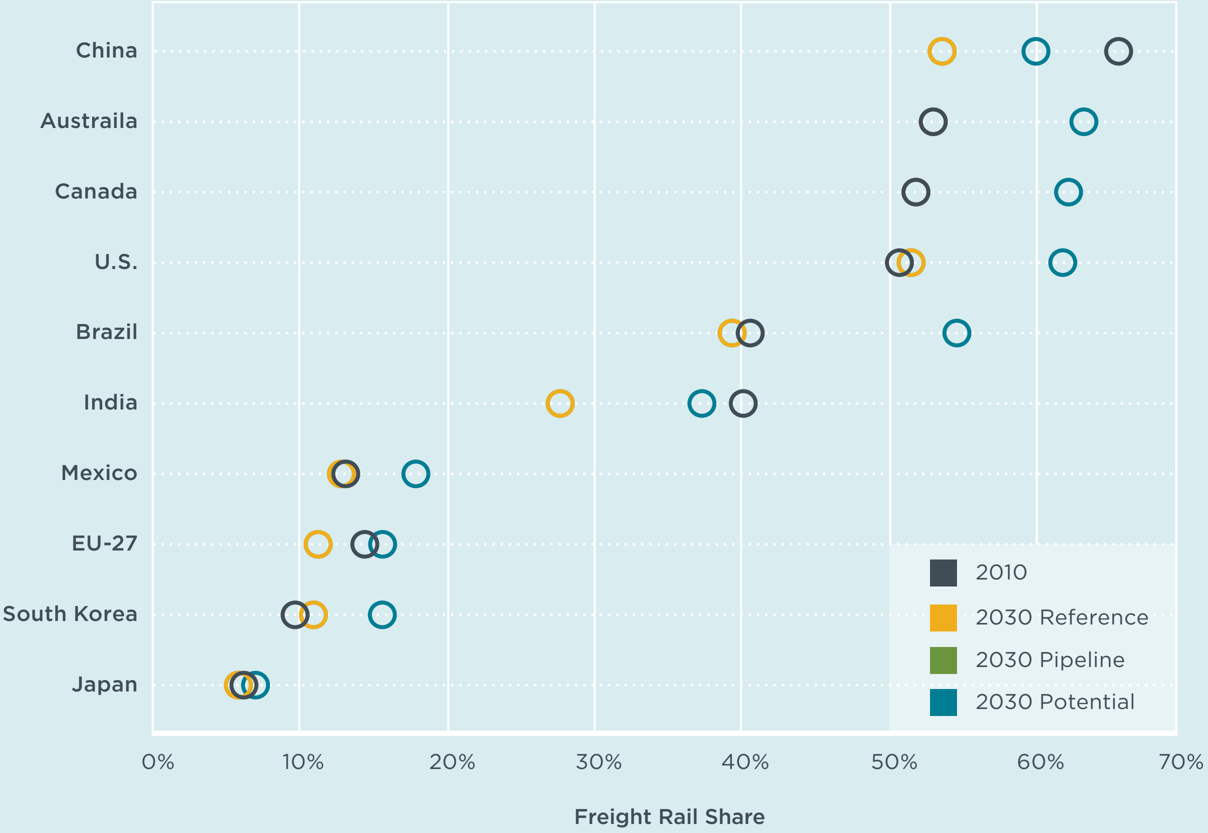

FIGURE 17. Freight Rail Mode Shares

Figure 18 illustrates the expected drop in GHG emissions from potential mode shift and activity reduction policies based on the assumptions in this analysis. The reductions from adopted policies are fully attributable to vehicle efficiency improvements, but a share of the reductions in the *Pipeline* trajectory come from public transit investments (96 $MtCO_2e$ in 2030). The potential in Figure 18 includes both mode shift and activity reduction policies, which combined could cut global GHG emissions by an additional 1.3 $GtCO_2e$ in 2030. These policies are vital to lock in sustainable development pathways and stabilize transportation GHG emissions. Furthermore, the importance of mode shift and activity reduction policies can be expected to increase beyond the 2030 time frame as economic development continues to drive growth in transportation activity.

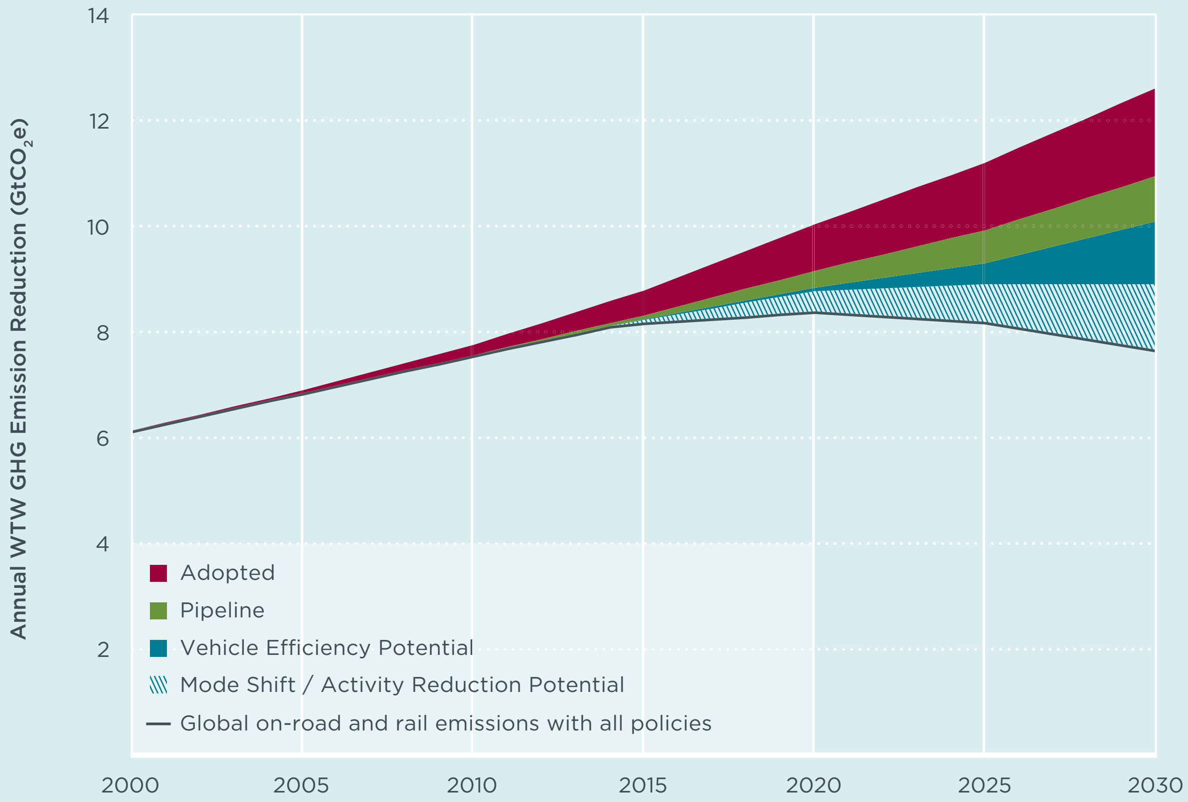

FIGURE 18. Mode Shift and Activity Reduction Potential GHG Reductions

7. COUNTRY/REGION ASSESSMENTS

This chapter features brief country/region policy assessments that highlight the effects of adopted, pipeline, and potential policies on energy and GHG emissions to 2030. Although a thorough evaluation of transportation policies in each of these regions is beyond the scope of this global analysis, the chapter provides an overview of the reductions in oil-equivalent consumption and GHG emissions that can be expected from the different types of transportation policies. Regions are ordered in terms of their total transportation GHG emissions in 2010.

Table 16 provides an overview of where and for what modes adopted, pipeline, and potential policies are considered. Policies to *improve* vehicle efficiency and *transform* the vehicle fleet to zero-emission technologies such as electric drive powered by renewable fuels encompass vehicle fuel efficiency or GHG standards, fiscal incentives, and mandates for potentially zero-emission vehicles, fuels, and fueling infrastructure. Policies to *shift* transportation activity from private automobiles and long-distance trucking to mass transit, nonmotorized transportation, and freight rail and to *avoid* transportation activity include mass transit and freight rail infrastructure investments alongside fiscal measures (i.e., taxes and user fees), travel demand management strategies, and land-use policies. Note that emission declines springing from mode shift and activity reduction measures completed prior to 2010 are not analyzed explicitly since these are already reflected in baseline historical activity data. A complete list of policy assumptions is offered in previous chapters. Aviation and marine emissions, which are assessed separately in previous chapters, are excluded from the country/region assessments.

TABLE 16. Summary of Policies Analyzed

Region / Mode	Improve			Transform	Shift*	Avoid
	LDV	HDV	Other			
United States	🔴🔵	🔴🔵		🔴🔵	🟢🔵	🔵
EU-27	🔴🟢🔵	🔴🔵		🔵	🟢🔵	🔴🔵
China	🔴🟢🔵	🔴🟢🔵		🔵	🟢🔵	🔵
India	🟢🔵	🔵		🔵	🟢🔵	🔵
Japan	🔴🔵	🔴🔵		🔵	🟢🔵	🔵
Brazil	🔴🟢🔵	🔵	🔴🟢‡	🔵	🟢🔵	🔵
Canada	🔴🟢🔵	🟢🔵		🔵	🟢🔵	🔵
South Korea	🔴🔵	🔵		🔵	🟢🔵	🔵
Mexico	🟢🔵	🟢🔵		🔵	🟢🔵	🔵
Australia	🟢🔵	🔵		🔵	🟢🔵	🔵
Marine			🔴🟢🔵			🟢🔵
Aviation			🟢🔵			🔴🟢🔵

🔴 Adopted 🟢 Pipeline 🔵 Potential ‡Fuels *Adopted mode shift policies included in *Pipeline.*

UNITED STATES

Transportation emissions in the United States declined from 2005 to 2010 as a result of diminished transportation activity during the economic recession in conjunction with light-truck fuel economy regulations adopted by the National Highway Traffic Safety Administration. In 1979 the United States first implemented fuel economy standards under the Energy Policy Conservation Act of 1975. Corporate Average Fuel Economy (CAFE) standards, which regulate the efficiency of passenger vehicles and light-duty trucks, remained relatively stagnant from the mid-1980s until the 2007 Energy Independence and Security Act mandated that they be tightened by 2020. The United States has issued fuel economy and GHG standards for light-, medium-, and heavy-duty vehicles.

Because the United States has finalized many vehicle efficiency policies through 2025 within the past few years, the potential effects of any further such policies to 2030 are limited. Adopted efficiency standards for on-road vehicles will result in 2030 emissions below 2000 levels, and additional decreases from vehicle efficiency improvements, mode shift, and activity reduction could cut 2030 emissions by 29 percent from 2000 levels. Reductions from all transportation policies could amount to 7 Mboe/day in 2030—more than all on-road and rail energy consumed in China in 2010.

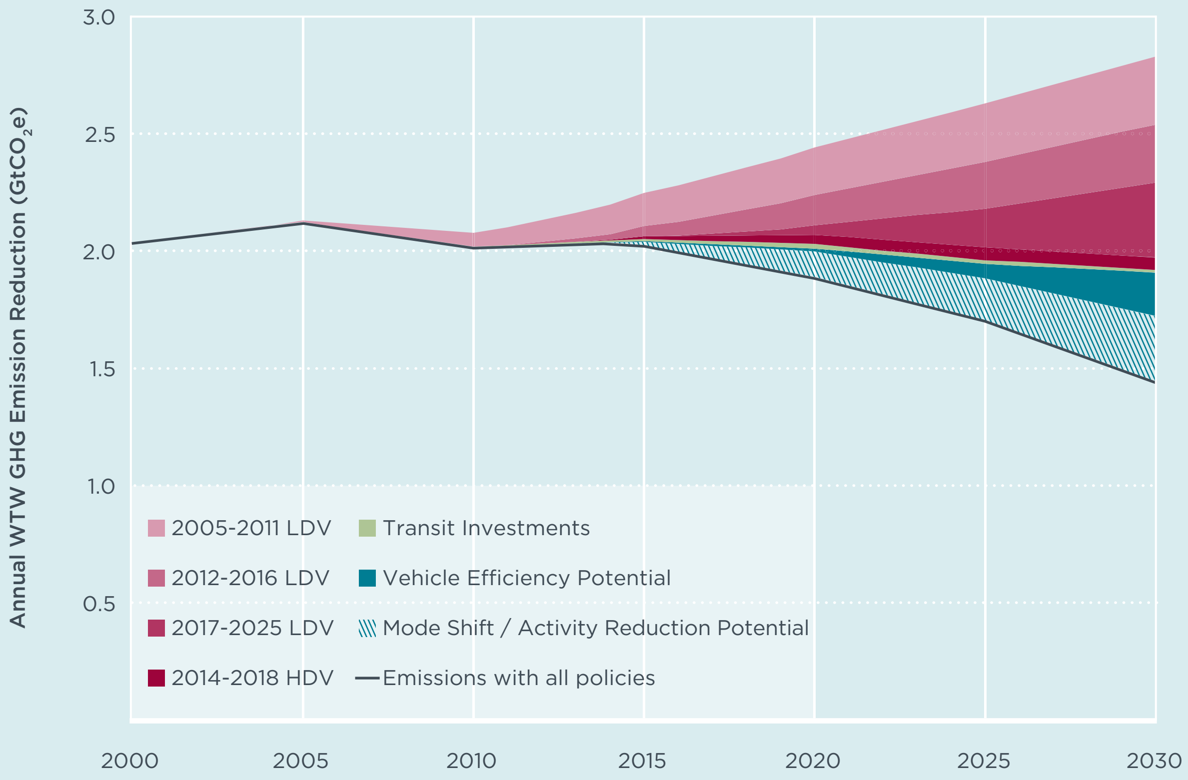

FIGURE 19. U.S. On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	38%	1.1%	-	-
ADOPTED	-6%	-0.2%	0.9	4.7
PIPELINE	-7%	-0.2%	0.9	4.7
POTENTIAL	-29%	-1.2%	1.4	7.0

EUROPE

Every fourth vehicle sold worldwide is produced in or imported into Europe, and its influence on the business decisions of major global vehicle manufacturers is significant. In the past, the European Union relied on a combination of voluntary targets and high fuel taxes to reduce GHGs from transportation. As a result of automakers failing to comply with voluntary targets, the EU adopted mandatory vehicle efficiency standards for LDVs and light commercial vehicles (LCVs), and in 2012 it adopted the 95gCO_2/km standard for new fleet-average LDV emissions in 2020. The EU is currently the only region in the world to target aviation CO_2 emissions through its regional CO_2 cap-and-trade system (discussed in Chapter 4). Many European cities and countries have also been leaders in adopting mode shift and activity reduction strategies to manage growth in motor vehicle traffic and encourage compact development and nonmotorized travel.

Adopted LDV standards have played an essential role in stabilizing emissions (excluding aviation) through 2030, and the light-duty standards in the *Pipeline* are expected to save an additional 0.13 GtCO_2e in 2030. The majority of reductions in the *Potential* trajectory are contingent upon more stringent standards for LDVs and HDVs. Together with mode shift and activity reduction strategies, these policies could slash EU emissions by 26 percent in 2030 from 2000 levels.

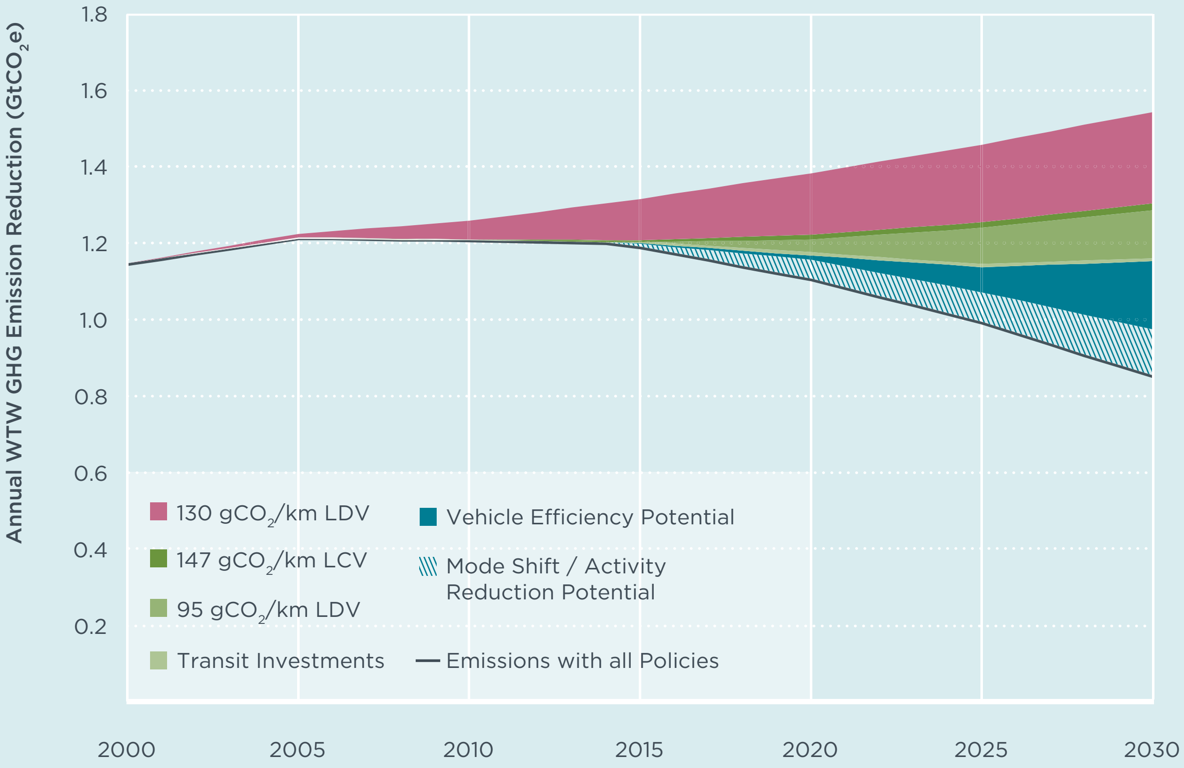

FIGURE 20. EU-27 On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	GtCO_2e	Energy (Mboe/day)
REFERENCE	36%	1.0%	-	-
ADOPTED	14%	0.4%	0.2	1.3
PIPELINE	1%	0.0%	0.4	2.0
POTENTIAL	-26%	-1.0%	0.7	3.5

CHINA

China's on-road and rail GHG emissions have grown rapidly since 2000 and, without policies beyond those adopted, are expected to grow at an average of more than 5.2 percent annually through 2030. Following China's pledge to reduce economy-wide carbon intensity by 40–45 percent by 2020 from 2005 levels, the national-level 12th Five Year Plan (FYP) and additional regional goals have been set based upon this target.[73,74] There is tremendous incentive in China to meet FYP objectives, including linking outcomes to career advancement for local government officials; however, the transportation sector share of these emission reduction goals has not been specified. Nonetheless, China has consistently adopted policies to improve the efficiency of both light- and heavy-duty vehicles, with subsequent and more stringent policies in the pipeline. Despite strong policy progress toward vehicle efficiency, there is still much uncertainty with respect to enforcement. With several hundred million people expected to move to China's cities over the next two decades[75], the pattern of urbanization and related transportation investment and policy will have a profound effect on long-term transportation energy use and emissions.

Despite rapid growth in activity thanks to the increasing wealth and mobility of the population, vehicle efficiency standards have the potential almost to stabilize emissions at 2020 levels. With the combination of vehicle efficiency, mode shift, and activity reduction policies, China could save about 5.8 Mboe/day in 2030—nearly the total energy consumed for on-road and rail transportation in the EU-27 in 2005.

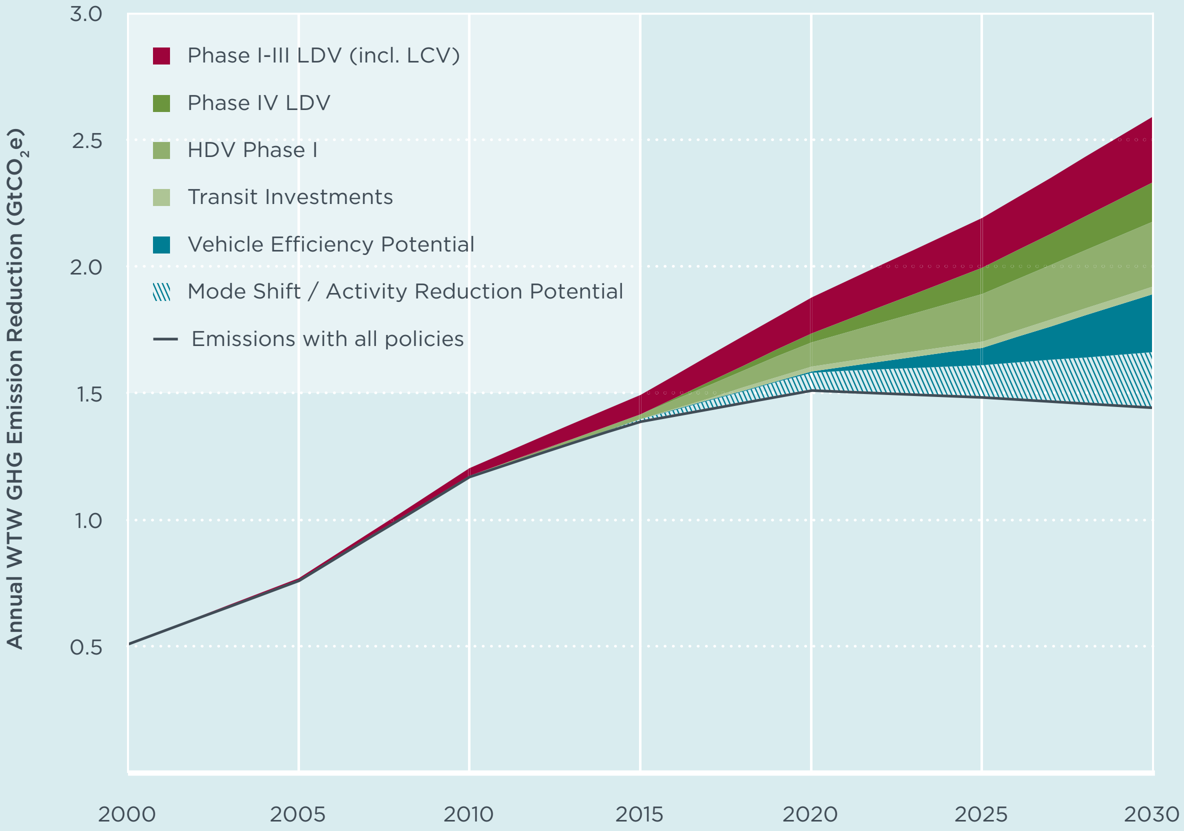

FIGURE 21. China On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	408%	5.6%	-	-
ADOPTED	357%	5.2%	0.3	1.4
PIPELINE	269%	4.4%	0.7	3.6
POTENTIAL	182%	3.5%	1.2	5.8

INDIA

Vehicle stock, transportation activity, and overall mobility have started to grow rapidly in India in recent years. As a result of low vehicle ownership rates, India currently has very low per capita transportation emissions. In light of India's rapid fleet expansion over the next decade and beyond, however, transportation emissions are expected to increase under all trajectories in this analysis.

On-road and rail emissions in India are forecast to grow at roughly 6.3 percent annually through 2030. While vehicle efficiency improvements could substantially limit the increase in emissions, activity-based measures have the potential to start to flatten out emission projections if implemented in conjunction with vehicle standards. Given that most emissions in 2030 are expected to come from on-road vehicles, shifting growth in passenger and freight activity to lower-carbon transportation modes such as public transit and freight rail could help India to reduce the energy, environmental, and congestion impacts of rapid growth of passenger vehicle and truck fleets. India has an opportunity to act before emissions begin to rise steeply.

Pipeline policies are largely focused on LDV efficiency standards. Unfortunately, policy measures that have long been announced, such as passenger vehicle fuel efficiency standards, are yet to be adopted formally.

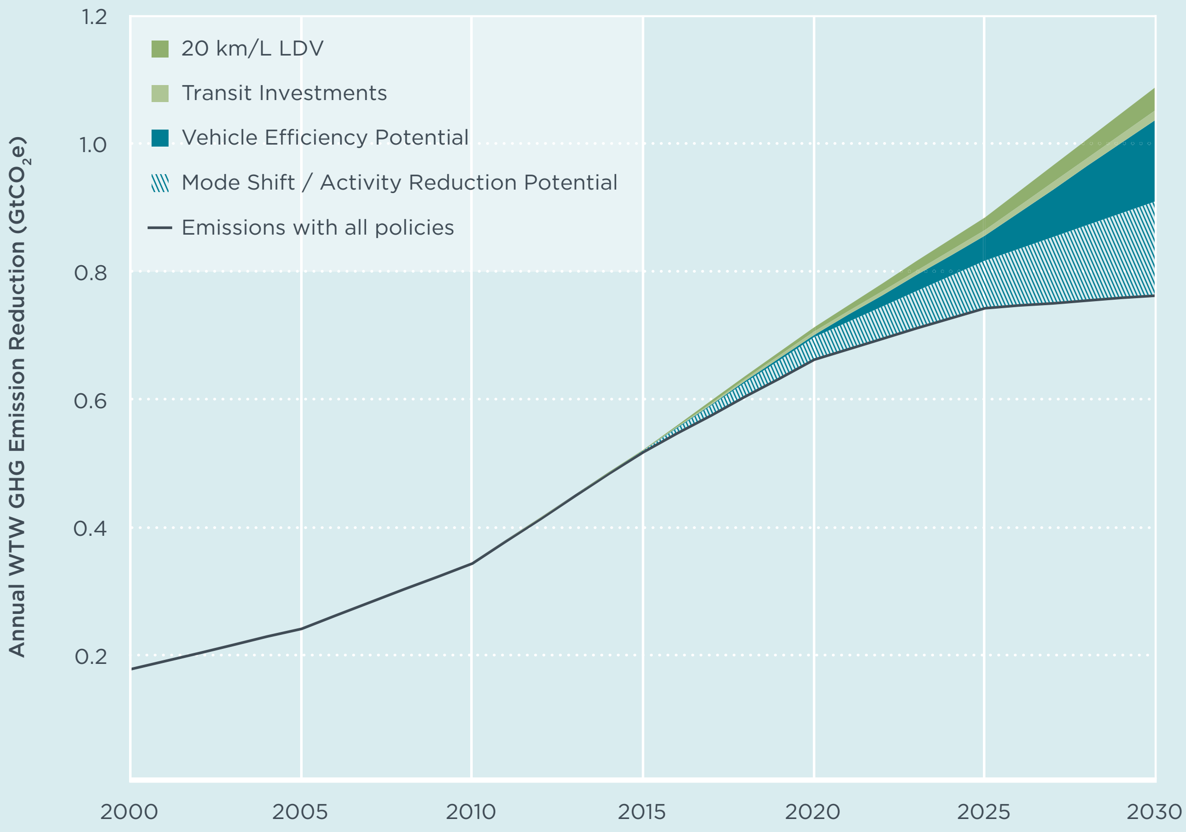

FIGURE 22. India On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	GtCO$_2$e	Energy (Mboe/day)
REFERENCE	518%	6.3%	-	-
ADOPTED	518%	6.3%	-	-
PIPELINE	473%	6.0%	0.08	0.3
POTENTIAL	323%	4.9%	0.35	1.7

JAPAN

Japan is somewhat of an outlier as the only country with decreasing transportation emissions under all scenarios explored. Japan was one of the earliest countries to adopt vehicle efficiency standards combined with fiscal incentives to raise of cost of vehicle ownership and to emphasize transit-oriented, walkable, and bikeable development in conjunction with pricing policies to manage transportation demand. These measures have led to very high rates of public transportation use and small average vehicle size. Net negative population growth, combined with the aging of Japan's large postwar generation and the falling popularity of cars for younger consumers, is expected to limit transportation demand growth further, particularly for motorized vehicles. On the other hand, compared to other countries, freight transportation in Japan is carbon intensive because of the importance of "just in time" goods movement and the prioritization of passenger rail over freight. Overall, however, projected trends in emissions and carbon intensity for Japan's transportation sector are expected to diverge considerably compared to other nations.

Japan was the first country to introduce HDV efficiency standards in 2005, though the standards will not fully take effect until 2015. Although CO$_2$ emissions would decline anyway in the absence of new policies, potential measures can cut 2030 emissions more than in half compared to 2000 levels.

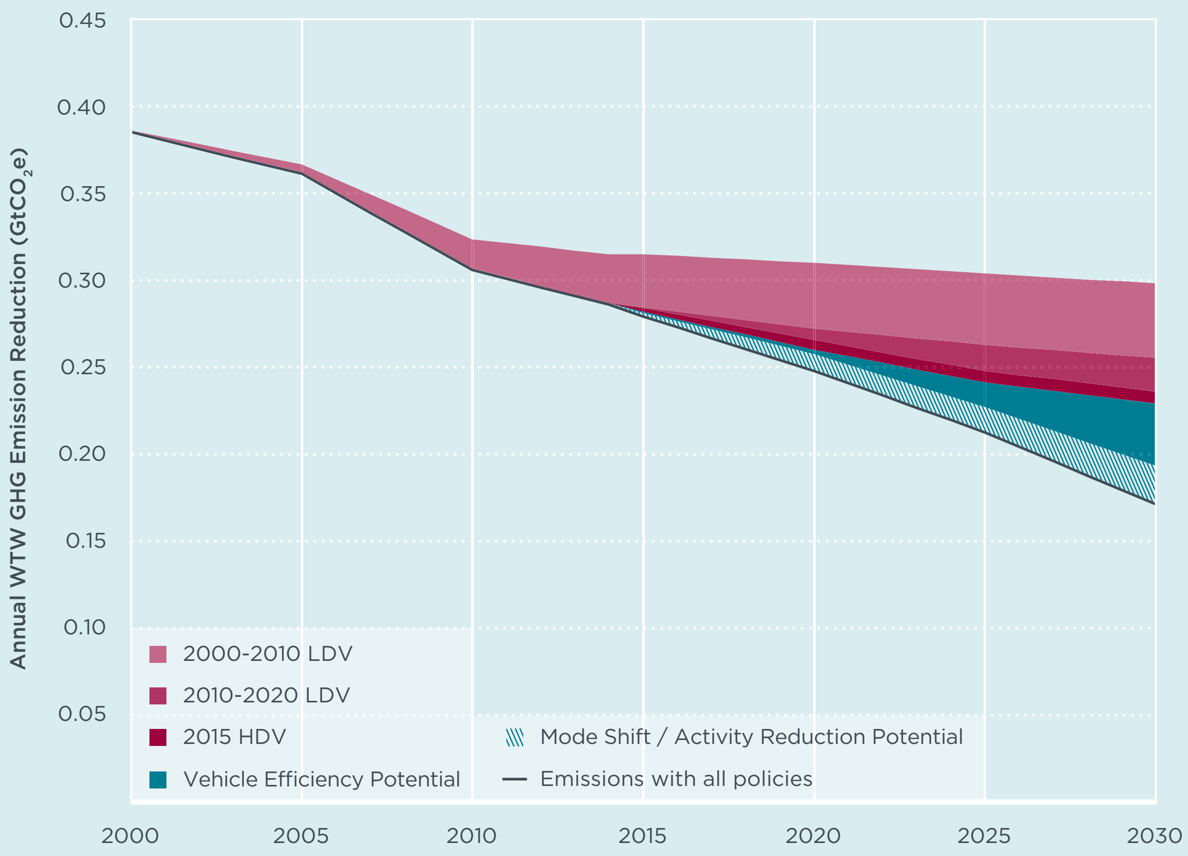

FIGURE 23. Japan On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	GtCO$_2$e	Energy (Mboe/day)
REFERENCE	-22%	-0.8%	-	-
ADOPTED	-41%	-1.7%	0.07	0.4
PIPELINE	-41%	-1.7%	0.07	0.4
POTENTIAL	-56%	-2.7%	0.13	0.6

BRAZIL

On-road and rail emissions in Brazil are expected to grow at 1.7 percent annually through 2030 based on policies that have already been adopted. Brazil has a well-established sugarcane ethanol industry supplying a substantial fraction of Brazilian road transportation fuel demand. The majority of technical studies support the assumption that Brazil's sugarcane ethanol delivers meaningful carbon reductions compared to conventional gasoline, even when indirect effects are accounted for. In addition, Brazil has a government-mandated ethanol blend in gasoline fuel, and in response to an ethanol shortage in early 2011, the Brazilian government has authorized the Petroleum National Agency (ANP) to regulate and control its production and distribution.

Brazil has long provided fiscal incentives to 1-liter-engine vehicles, which has had a profound effect on the average fleet size. In 2012, it revised its fiscal incentives to incorporate more explicitly vehicle efficiency, which is expected to reduce new LDV fuel consumption by 12 percent by 2017 from today's levels, with additional 7 percent efficiency improvement in the pipeline.

While adopted and pipeline vehicle efficiency improvements, support for ethanol, and transit investments will limit the growth in transportation-related emissions, only with the introduction of new (and more aggressive) vehicle efficiency, mode shift, and activity reduction policies in the *Potential* trajectory will Brazil be able to return emissions to roughly 2000 levels.

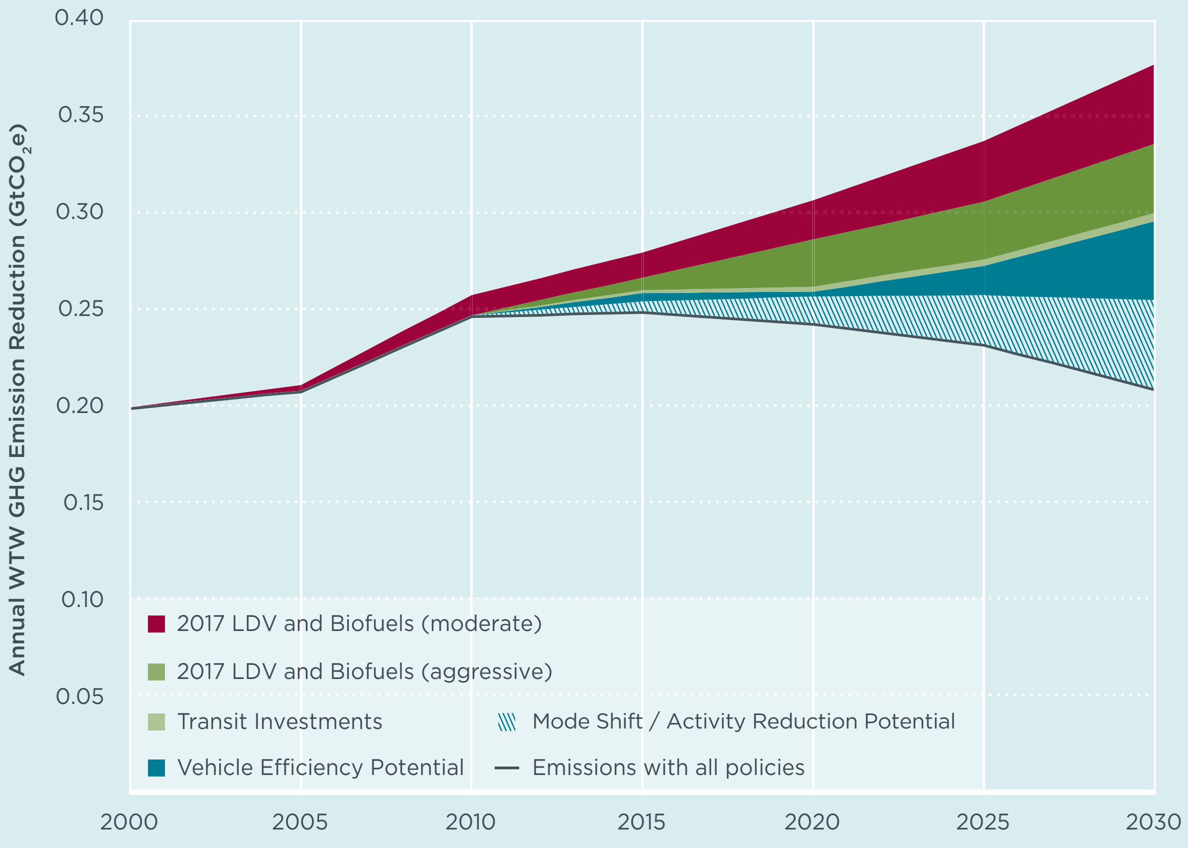

FIGURE 24. Brazil On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	89%	2.1%	-	-
ADOPTED	68%	1.7%	0.04	0.17
PIPELINE	48%	1.3%	0.08	0.2
POTENTIAL	5%	0.2%	0.17	0.8

CANADA

Canada's emissions have remained relatively stable in the past decade, and adopted vehicle efficiency policies for the new light- and heavy-duty fleets will keep transportation emissions roughly at 2000 levels. Canada has historically harmonized its national vehicle emissions standards with those of the United States, and beginning in 2007 it extended harmonization to U.S. CAFE standards, while matching the EPA's GHG regulations beginning in 2011. To date, Canada has issued harmonized LDV standards to 2016, proposed harmonized HDV standards, and announced plans to harmonize LDV standards out to 2025.

If Canada harmonizes with the U.S. 2017–25 rule for LDVs, on-road and rail emissions in 2030 will tip below 2000 levels. Additional vehicle efficiency potential improvements, alongside activity reduction and mode shift policies, can change the trajectory of Canada's transportation emissions, trimming them by 26 percent from 2000 levels.

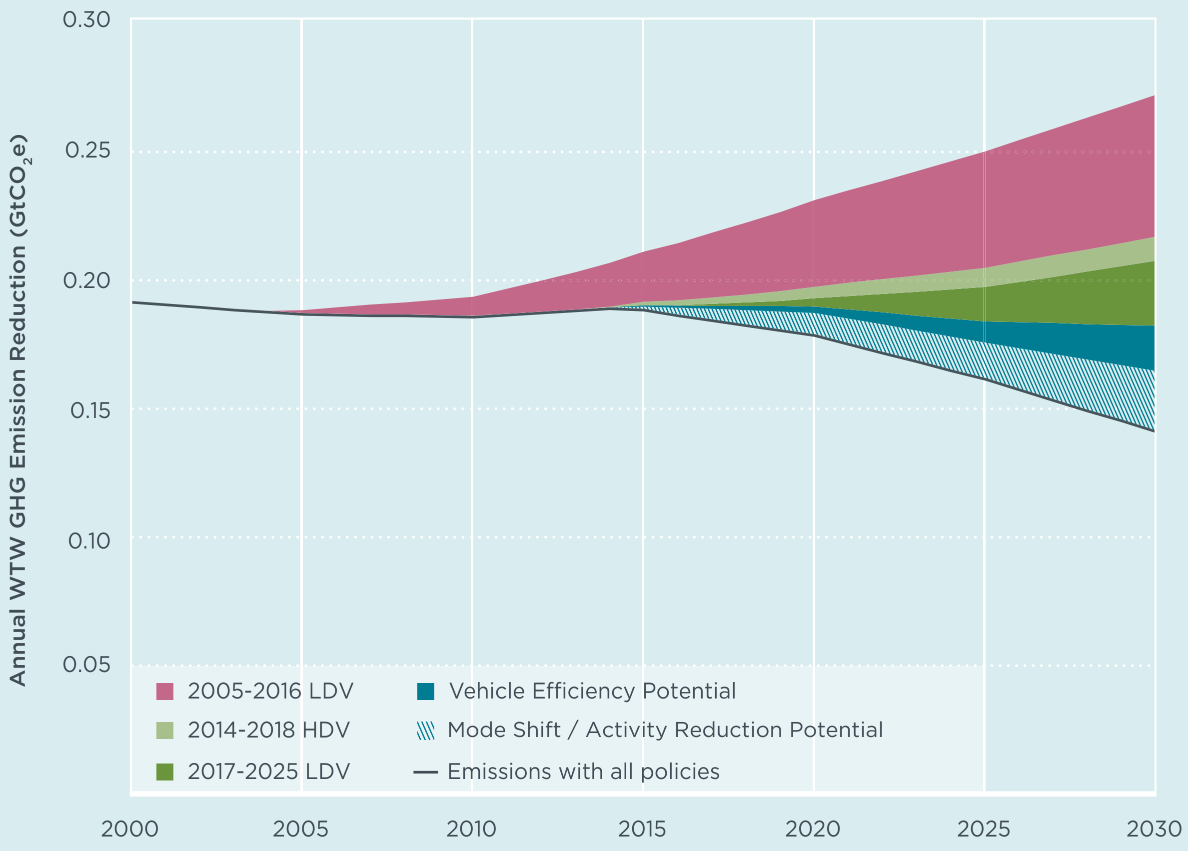

FIGURE 25. Canada On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	38%	1.1%	-	-
ADOPTED	10%	0.3%	0.05	0.3
PIPELINE	-5%	-0.2%	0.08	0.4
POTENTIAL	-26%	-1.0%	0.12	0.6

SOUTH KOREA

In 2011, South Korea was one of the more heavily motorized countries, ranked in the top third of countries in terms of vehicle ownership with 379 vehicles per 1,000 people. In addition to being a major market for cars, South Korea is also an important manufacturer, producing 5 percent of new cars globally in 2010.[76] The major policy success in South Korea's transportation sector has been the implementation of fuel economy/CO_2 emissions standards for LDVs through MY2015, which are complemented by fiscal incentives for hybrid vehicles.

Accounting for the Average Fuel Economy (AFE) program already, South Korea's emissions are expected to grow roughly by 2.3 percent annually through 2030. Vehicle efficiency potential reductions include subsequent phases of LDV standards, new HDV standards (currently under discussion), and policies that promote electric vehicle sales, as well as mode shift and activity reduction strategies. If implemented within feasible but aggressive timelines, these policies could start to tip the emissions trajectory downward starting in 2020.

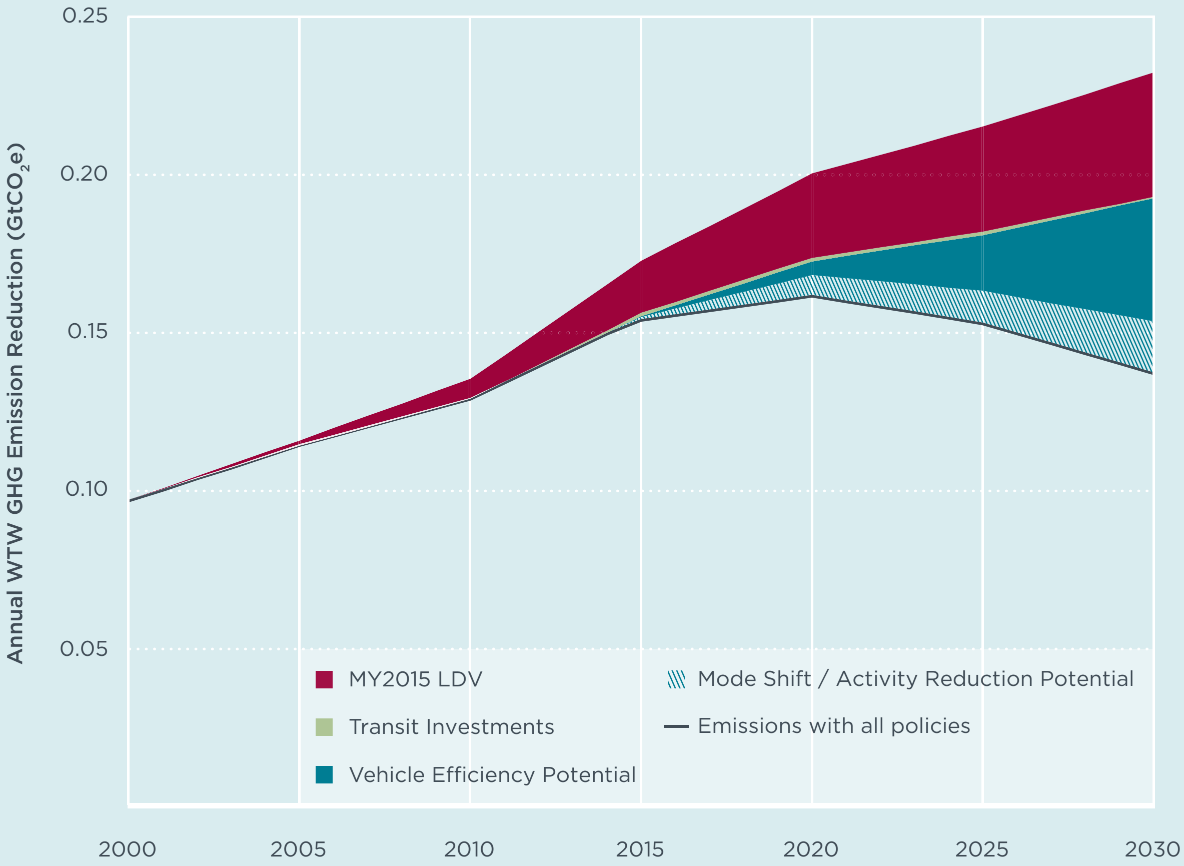

FIGURE 26. South Korea On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	140%	3.0%	-	-
ADOPTED	99%	2.3%	0.04	0.2
PIPELINE	99%	2.3%	0.04	0.2
POTENTIAL	42%	1.2%	0.10	0.5

MEXICO

Transportation activity in Mexico doubled in the first decade of the millennium and is expected to increase by another 75 percent out to 2030. In the absence of policy action, Mexico's emissions are forecast to grow by 2.7 percent annually through 2030, more than doubling emissions from 2000 levels.

Mexico is a net oil exporter, and the government relies heavily on oil revenues. In recent years oil production has begun to fall (16 percent since 2007), while internal consumption continues to grow, resulting in declining export earnings.[77] This provides a strong incentive for the country to reduce fuel consumption from the domestic fleet. In addition, in 2012 Mexico passed a climate change law seeking reductions of GHG emissions by 30 percent in 2030, demonstrating a strong commitment to dealing with the issue.[78] A number of transportation policies are in the pipeline, including LDV and HDV efficiency regulations and important transit investments. Mexico is seeking to harmonize vehicle efficiency standards with the United States and Canada out to 2016 for LDV standards and 2018 for HDV standards. It has invested heavily in improving public transportation in recent years; it has greatly expanded BRT systems in Mexico City and has begun building similar systems in many other major cities as well. With transit mode shares of 60 percent as recently as 2000 and growing frustration with urban congestion, there is a tremendous potential to slow the growth in passenger vehicle activity in Mexico.

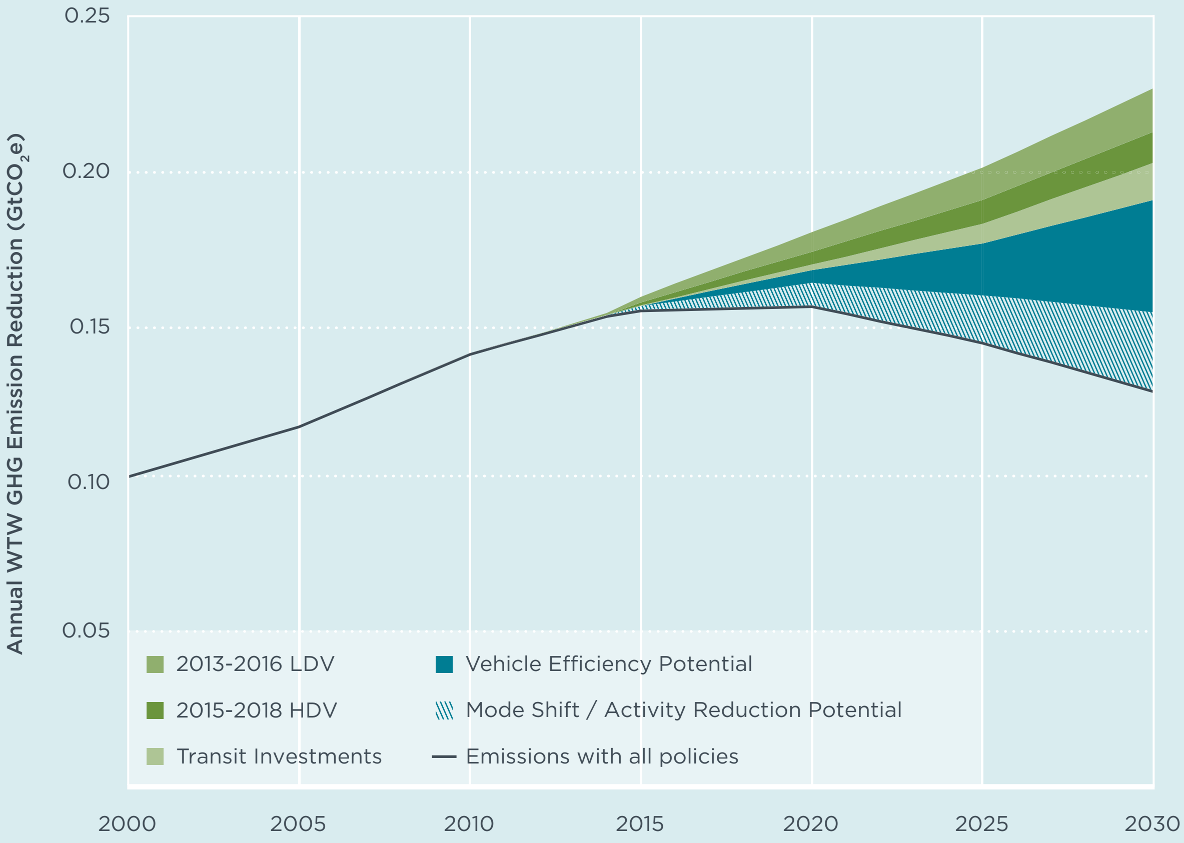

FIGURE 27. Mexico On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	121%	2.7%	-	-
ADOPTED	120%	2.7%	0.00	0.0
PIPELINE	86%	2.1%	0.04	0.2
POTENTIAL	27%	0.8%	0.10	0.5

AUSTRALIA

Transportation GHG emissions in Australia are forecast to increase by almost 50 percent by 2030 from 2000 levels. Australia's per capita energy consumption and GHG emissions rival those of the United States. Carbon pricing, introduced as a part of the Clean Energy Future plan, largely excludes the transportation sector. Instead, Australia is planning mandatory CO_2 standards for all LDVs from 2015 onwards. These standards build off of a previous voluntary commitment by the automotive industry to reduce new LDV fleet-average CO_2 emissions to 222 grams/kilometer by 2010. In addition, the Australian government has invested more than AUS $7 billion (roughly U.S. $7 billion) in urban passenger rail infrastructure since 2007.[79]

The 2020 standards under discussion for LDVs and LCVs have the potential to stabilize transportation emissions through 2030. Combined with additional vehicle efficiency improvements, mode shift and activity reduction policies could save roughly 0.3 Mboe/day and bring emissions in 2030 to below 2000 levels.

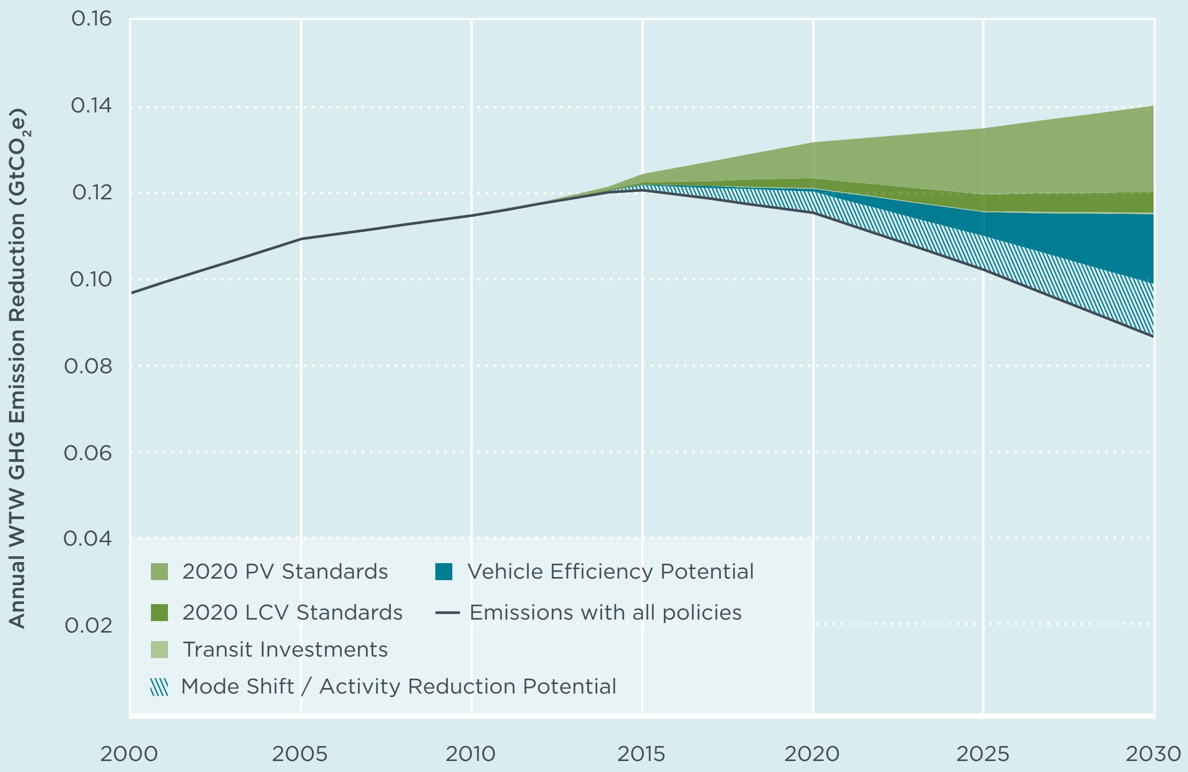

FIGURE 28. Australia On-road and Rail Emission Trajectories

Trajectory	Emissions Growth (2000-2030)		Total Reduction in 2030	
	Total	Annualized	$GtCO_2e$	Energy (Mboe/day)
REFERENCE	48%	1.3%	-	-
ADOPTED	48%	1.3%	0.00	0.0
PIPELINE	18%	0.6%	0.03	0.1
POTENTIAL	-10%	-0.4%	0.06	0.3

8. CONCLUSIONS

Adopted policies since 2000 in many of the main vehicle markets will have a dramatic impact on global oil consumption and GHG emissions from the transportation sector. Policies currently in the pipeline will augment the benefits of adopted policies. This analysis also considers potential policies, grounded in technical feasibility studies, resulting in a more ambitious emission reduction trajectory out to 2030 than can be achieved by only considering policies in active development as of 2012. The complete suite of transportation policies—including those targeting vehicle efficiency improvements as well as shifts to less energy-intensive modes and activity reduction—will result in global oil and GHG emission cuts of 28.6 Mboe/day and 5.8 GtCO$_2$e in 2030, respectively, equivalent to a 28 percent decline in oil consumption from the International Energy Agency's forecast and a 14 percent drop in global economy-wide GHG emissions in 2030 (Figure 29).[80]

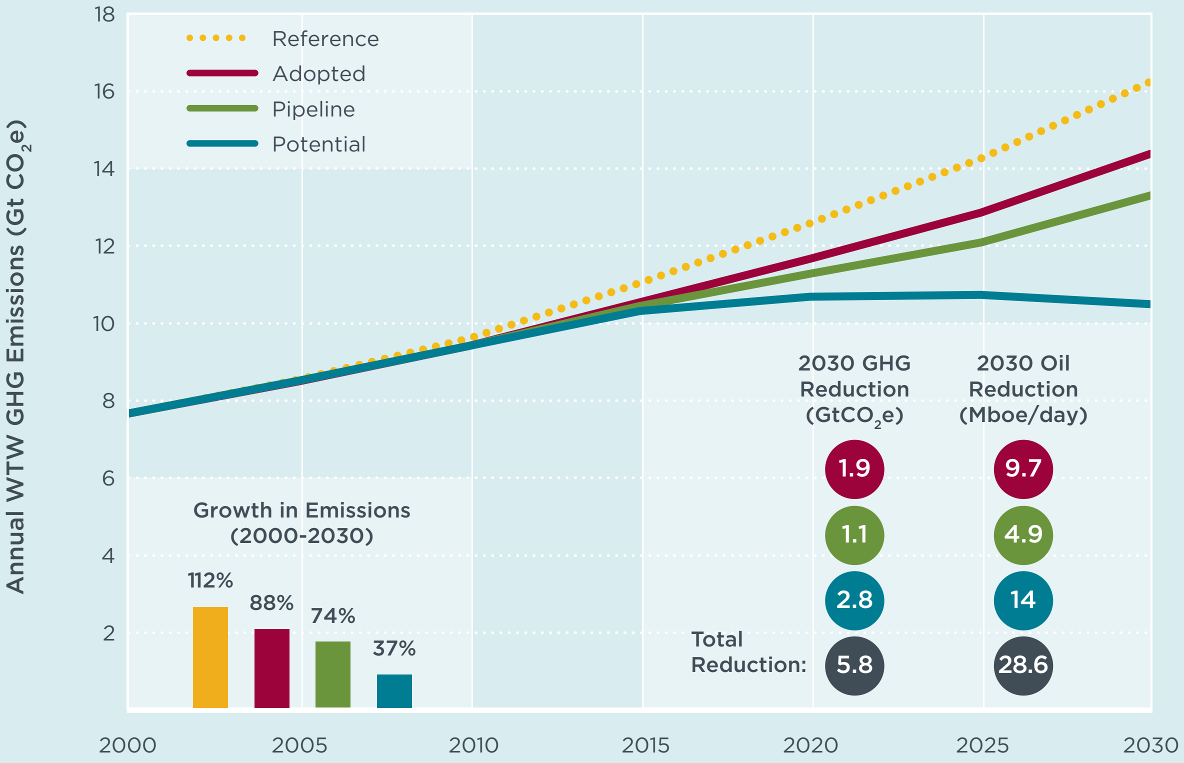

FIGURE 29. Global Transportation Emission Trajectories

Studies by the Intergovernmental Panel on Climate Change (IPCC) have indicated that global GHG emissions need to be reduced from 50 to 85 percent from 2000 levels by 2050 to constrain temperature increases to two degrees Celsius, the agreed-upon global climate change mitigation goal in the 2009 Copenhagen Accord.[81,82] While transportation policies evaluated in this analysis could essentially allow for stabilization of global transportation emissions just below those of 2010, their efficacy would not be sufficient to put the transportation sector on the pathway to 50–85 percent emission reductions. Meeting long-term climate goals within the transportation sector will require strong policy action both before and after 2030, including a continuation of vehicle efficiency improvements, the aggressive deployment of potentially zero-carbon vehicle technologies, and significant shifts to less energy-intensive modes, all of which can be facilitated through strong fiscal policies to help internalize the carbon impacts of transportation.

APPENDIX A. SELECTION OF GREENHOUSE GASES

Three greenhouse gases (GHGs)—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—were analyzed in the present Roadmap model as a consequence of their regulation under the Kyoto Protocol and their large contribution to global climate effects. The Kyoto Protocol requires reductions in six long-lived greenhouse gases that are well understood by the climate science community: CO_2, CH_4, N_2O, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF_6).[83] Combined, CO_2, CH_4, and N_2O accounted for more than 87 percent of global radiative forcing (see the following paragraph for definition) caused by the Kyoto gases since the preindustrial period up until 2005. The halogenated species (PFCs, HFCs, and SF_6) are not included in this study but will be added at a future date, given the large emissions, particularly HFCs, from mobile air conditioning.

GLOBAL CLIMATE CHANGE IMPACTS OF TRANSPORTATION

Because the relative importance of these GHGs varies by sector, it is necessary to consider transportation-specific emissions profiles. The transportation sector accounts for 21 percent of all anthropogenic CO_2 emissions, 19 percent of volatile organic compounds (VOCs), 18 percent of carbon monoxide (CO), 14 percent of black carbon (BC), and 10 percent or less of the remaining United Nations Framework Convention on Climate Change–identified climate-forcing agents.[84] In terms of direct climate impacts, it is useful to transform these emissions into a measure of the amount of energy trapped in excess of preindustrial levels, called radiative forcing (RF), which is expressed as a ratio of megawatts to square meters. Positive radiative forcing causes increases in global and regional temperatures, while negative forcing causes decreases. By the year 2000, transportation contributed about 15 percent and 31 percent of total positive RF from anthropogenic sources of CO_2 and ozone (O_3), respectively. Specifically, CO_2 accounts for the largest fraction of transportation-attributable RF (230 mW/m^2), with road transport being the predominant subsector (150 mW/m^2 or 10 percent of total anthropogenic RF). The shipping and aviation subsectors contribute an additional 35 and 21 mW/m^2, respectively. The second-most important GHG contributing to positive transportation RF is tropospheric O_3. In all, the transportation sector represents a sizable contribution to anthropogenic RF from the most potent GHGs.

By subsector, the relevant non-CO_2 emissions from land-based transportation include BC, HFCs, CO, and ozone precursors—nitrogen oxides (NO_x) and VOCs. However, the atmospheric chemistry of these last three gases also generates hydroxyl (OH) radicals, which are a reactant in the removal mechanism of CO and CH_4 from the atmosphere.[85] As a result, land transportation results in a negative RF for CH_4. Though N_2O is a much more potent GHG than CO_2, it is emitted in low, though not negligible, quantities from road transportation. BC emissions from land transportation account for nearly a quarter of global emissions, almost 90 percent of which is contributed by diesel engines. Climate change impacts of the aviation and shipping subsectors result from the release of species similar to those from road transportation, although marine vessels are a significant source of sulfates that cause cooling, while the aviation sector is a unique source of cirrus-induced cloudiness and persistent contrails.[86,87]

CLIMATE METRICS

This report compares emissions by region on the basis of carbon-equivalent tonnes. Doing so facilitates analysis of multiple pollutants with a single metric and is a common convention for comparing climate-relevant pollutants that vary in their impact. The IPCC reports a weighting factor called the Global Warming Potential (GWP) to facilitate this conversion. Each GWP is a ratio of the integrated radiative forcing of a pollutant (i.e., instantaneous forcing of a pulse emission of the pollutant multiplied by its lifetime) relative to the integrated radiative forcing of an equivalent mass of carbon dioxide. When used to convert to CO_2-equivalents, GWP is equal to working units of mass of CO_2e per mass of pollutant. This conversion method is used to express emissions and emission reductions in terms of CO_2e throughout the report. The IPCC reports three GWP values for each pollutant based on the time horizon of integration: 20 years, 100 years, and 500 years.[88] In accordance with UNFCCC reporting requirements for national GHG inventories, the chosen time horizon in this report is 100 years.[89] As scientific understanding of the transport, atmospheric chemistry, and impacts of the short-lived pollutants such as tropospheric ozone, BC, and aviation-induced cirrus becomes more sophisticated, interest in incorporating these pollutants into GHG inventories has grown. However, application of the 100-year time horizon for the GWP raises concerns, as it understates the climate contribution of short-lived pollutants relative to long-lived GHGs (LLGHGs). The choice to use this time horizon for the report is in the spirit of consistency and comparability with the bulk of the climate change mitigation policy literature, which is predominantly CO_2- and LLGHG-centric.[90] Subsequent work at the ICCT will explore alternative time horizons with evaluation of local and short-lived pollutants.

APPENDIX B. MARINE MARKET-BASED MEASURES

The main measures under discussion for future regulations to mitigate GHG emissions from marine vessels are various forms of market-based mechanisms (MBMs) for ship GHG emissions as outlined in the IMO document MEPC62/5.1. The nine proposals range from fuel levies that would fund out-of-sector GHG reduction initiatives in developing countries to cap-and-trade systems that would raise and spend money entirely within the shipping sector based on the efficiency of new ships. These various measures were analyzed by an expert group (MBM-EG) appointed by the Marine Environment Protection Committee chairman and reported in MEPC61/INF.2.

EMISSION TRADING SCHEMES (ETS)

Norway, France, and the United Kingdom are the main supporters of emission trading schemes. Under Norway and France's proposal, the CO_2 allowance, subject to an annual sector-wide cap set up by the IMO, will be allocated to each individual ship, either free of charge or through an auction. Ships need to open an account in an international ETS registry, acquire emission allowances, and keep records of their bunker consumption. The flag administration or recognized organization (RO) will use a survey and certification regime to monitor ship compliance. The ETS would be linked with other ETS markets so that the emission units are exchangeable. In addition, ships can purchase emission credits through Clean Development Mechanisms (CDM) projects. A newly created international entity is in charge of the revenue generated by auctioning emission allowances. The funds can be used for climate change mitigation and adaptation purposes in developing countries as well as technical cooperation activities under the aegis of the IMO. This mechanism needs a new legal framework administered by the IMO.

Similar to the Norway/France ETS in most respects, the U.K. ETS proposal differs in two ways. First, instead of establishing a new institution to allocate emission allowances, the United Kingdom suggests that they to be allocated to national governments for auctioning. Second, the U.K. proposal suggests that the net emission cap be set with a long-term declining trajectory in discrete phases (i.e., five to eight years), with an initial introductory or transitional phase of one to two years.

In spite of their differences, the effect of the different ETS proposals on CO_2 reduction was assumed to be identical. The IMO expert working group (WG) estimated a reduction of 452 $MtCO_2$ in 2030 through offsetting, with an additional 60 $MtCO_2$ reduction through efficiency improvements. The scheme would cost U.S. $49 billion.

GHG FUND

Cyprus, Denmark, the Marshall Islands, Nigeria, and the International Parcel Tankers Association (IPTA) are sponsoring a proposal for a GHG Fund. Under the GHG Fund, a new convention will mandate the registration of bunker fuel suppliers located within the territory of a state party. Suppliers located in a non–state party will be registered on a voluntary basis. Party-flagged ships will be required to purchase fuels from registered bunker fuel suppliers, which in turn will issue a bunker delivery note that should be kept on board for future inspections by the port state. The flag state needs to monitor and enforce convention obligations. A GHG contribution is generated whenever ships purchase bunker fuel. The revenue is then transferred to the international GHG Fund by the registered bunker fuel supplier or alternatively by the ship owner. Managed by the GHG Fund administrator, the fund will be used to purchase emission credits to meet the emission limits set by the UNFCCC or the IMO.

The proposal was estimated to rely on more offsetting than the ETS but might entail fewer gross costs. The total CO_2 emission reduction would be similar to ETS's at 522 $MtCO_2$ in 2030, and the gross cost is expected to be U.S. $25 billion.

PORT STATE LEVY (PSL)

Instead of depending on bunker suppliers, Jamaica's proposal suggests levying a uniform emission charge, the port state levy (PSL), on all vessels calling at their respective ports based on the amount of fuel consumed by the vessel on its voyage. Fuel consumption is monitored by fuel consumption meters, now commonly installed in large vessels, and is inspected by the port state. Existing voyage models would be used to audit fuel consumption and efficiency improvements declared by vessels. The revenue, collected by a newly established administration at the port state, can be used to offset CO_2 emissions or reward ships that increase energy efficiency. Notably, if the entire revenue is devoted to the latter purpose, the PSL falls into the in-sector reduction category.

The PSL proposal still lacks key information such as the mechanism for setting the levy and how to use the revenue. The IMO's WG was only able to calculate a 64 $MtCO_2$ in-sector reduction with U.S. $49 billion gross costs by 2030.

REBATE MECHANISM (RM)

Unlike the three proposals above, which require all ships to reduce CO_2 emissions, the International Union for Conservation of Nature's (IUCN) Rebate Mechanism (RM) is designed to ensure that developing countries are reimbursed for their costs resulting from a MBM, so that the MBM has "no net incidence" for them, an important point insisted by major developing countries. The mechanism can be added to other MBM options as long as they generate revenues. Under the RM, a central emission registry is created by a new convention to keep an emission account for each ship. When ships purchase bunker fuel, they report the purchase to the account and pay a fee to a newly created bank. The status of compliance is monitored and enforced by the flag state and the port state. The bank will distribute part of the revenue to developing countries and use the remainder to purchase offsets.

The RM is reckoned to reduce CO_2 by 409 $MtCO_2$ in 2030, with 345 $MtCO_2$ coming from out-of-sector reduction. The gross cost is expected to be U.S. $49 billion by 2030.

SHIP EFFICIENCY AND CREDIT TRADING (SECT)

Proponents of in-sector reduction question the effectiveness of carbon offsets, citing additionality as the chief concern. With respect to carbon pricing of fuel, they contend that it is market barriers, not the lack of price signals, which fail to incentivize shipping firms to increase their fuel efficiency. If these market barriers are not addressed, they argue, an increase in fuel price would not achieve the intended fuel savings. Instead, they support mandatory energy efficiency improvement as the primary means to reduce CO_2 emissions from international shipping.

The Ship Efficiency and Credit Trading proposed by the United States is one of the MBMs focusing on in-sector emission reductions. The SECT aims at establishing an efficiency-credit trading program for both new and existing fleets. The stringency level of the efficiency standard will increase over time, based on energy efficiency technologies available to ships in the fleet. Less efficient ships that fail to meet the stringency requirement will have to purchase credits from more efficient ships. Further information will be needed to explain the compliance mechanism when the ship is in operation and to describe how to collect and verify activity data as the basis for the system's credit trading. Lacking adequate stringency information, the IMO's WG was only able to estimate the in-sector reduction of the SECT to be 142 $MtCO_2$ in 2030 by assuming the stringency standard is set as equivalent to the EEDI for new ships.

BAHAMAS PROPOSAL

In contrast to several competing measures, the Bahamas proposal seems to be gaining increasing traction. The proposal suggests that ships increase energy efficiency through retrofitting technologies and operational strategies by a certain percentage based on their ages. The baseline is primarily founded on three years of bunker delivery notes, taking into account any significant changes in the trading pattern of the vessel as well as of periods of layup. The flag state or RO would undertake a survey of the vessel to assess the emissions, determine the reduction level, and issue the appropriate international CO_2 reduction certificate. Strictly speaking, the proposal is characterized by many delegations as an alternative to MBMs. European countries, on the other hand, regard it as an interim approach before countries agree to an ETS or levy.

The cost and benefits of the Bahamas proposal were not modeled by the IMO's WG due to lack of data and information at the time. Based on latest information, the ICCT estimates that the Bahamas proposal could achieve an in-sector reduction of 132 $MtCO_2$ in 2030.

APPENDIX C. BIOFUELS POTENTIAL

While this analysis does not include any contribution from biofuels toward achieving carbon reductions (with the exception of sugarcane ethanol in Brazil), there are several studies, including studies led by federal governments or prominent international agencies, that argue for significant technical potential for fuel production and carbon savings from biomass. The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation,[91] the IEA Bioenergy Roadmap,[92] and the UK Committee on Climate Change Bioenergy Review[93] provide bioenergy potential estimates based on reviews of a main pool of literature studies; these reviews present estimates of 2050 bioenergy production potential of up to 1600 exajoules per year (EJ/yr). For comparison, the heat equivalent of all biomass harvested today (including for food) is 219 EJ/yr.[94] To achieve the levels of biomass production projected by some of these studies while preserving food quantity and quality would require some combination of major changes in land use and very optimistic assumptions about future crop yields, population size, and diet. Several of these academic studies assume unrealistically high crop yields,[95,96] low meat consumption in some scenarios,[97,98] or widespread expansion onto natural lands.[99,100]The studies that make more reasonable assumptions in these areas[101,102] provide estimates of biomass potential that, while likely still optimistic, are more plausible. Most of these studies do not consider market limitations (e.g., demand or cost), nor do they try to assess exactly which policies would yield the suggested outcomes or what might be the unintended consequences of the types of policies aiming at these outcomes. It is also important to consider that biofuels will have to compete for biomass with bioelectricity and bioheating and that some energy losses will occur upon conversion.

This analysis reviewed and reassessed nine prominent studies on future bioenergy potential based on more plausible and sustainable assumptions and estimates that a maximum of 106 EJ/yr of primary energy may be available in 2050.[103,104,105,106,107,108,109,110,111] This estimate is still based upon optimistic assumptions and should be considered an upper limit to what the real potential will be. The analysis suggests that only about one-third of this is likely to be available for biofuels and after conversion losses will deliver a maximum of 21 EJ/yr in biofuel. To put this in perspective, the energy demand from the transportation sector today is approximately 100 EJ/yr, and the level needed for the sector to achieve an 50 to 85 percent reduction from 2000 levels would be 12 to 41 EJ/yr. An IEA analysis of the expected market for biofuel in 2050 predicts a demand of about 32 EJ/yr, as well as demand for bioelectricity and bioheating of 60 EJ/yr. While the IEA-projected demand may not be able to be met sustainably, biofuels could play a critical role in achieving 2050 GHG reduction goals.

It is worth noting that, in contrast to the variety of studies that find a substantial technical potential for biofuels, several recent reports with more of a food security focus have advocated the abandonment of the current generation of biofuel policies. For instance, a 2011 report[112] to the G20 by the Food and Agriculture Organization, the International Fund for Agricultural Development, the International Monetary Fund, the Organisation for Economic Co-operation and Development, the UN Conference on Trade and Development, the World Food Programme, the World Bank, the World Trade Organization, the International Food Policy Research Institute, and the UN Secretary-General's High-Level Task Force recommended that "G20 governments remove provisions of current national policies that subsidize (or mandate) biofuels production or consumption." There is a tension between the conflicting objectives of increasing the energy supply and protecting food security and natural areas that is not adequately captured when considering technical potential alone.

A major problem with the consideration of any sort of 'technical potential' estimates for biomass availability when the focus is on GHG reductions is that there is a critical difference between how biofuel could be produced and how biofuel actually would be produced if policy drivers were put in place or if market conditions made biofuel supply profitable without support. There is certainly substantial potential in principle for GHG mitigation through the use of biofuels, but the reductions that would be realized in practice will depend heavily on land management regulation. If biofuel expansion drives carbon emissions through land-use change, these could be on a comparable scale to the 'direct' savings. Life-cycle analyses that include modeled indirect land-use-change-related emissions for current corn bioethanol production pathways in the United States by both the EPA and the California Air Resources Board find that most corn ethanol production offers limited or no carbon saving compared to gasoline. Other ethanol pathways, notably from sugar crops, are generally estimated to offer larger potential savings;[113,114] it is expected that cellulosic ethanol produced from dedicated energy crops (such as perennial grasses, woody crops, or agricultural and forestry residues) is also likely to have lower carbon intensity. It is probable that in the absence of stricter controls on global land use, biodiesel produced from vegetable oils will have equal or higher carbon intensity than diesel.[115] Most projections of future biomass production, especially past 2020, do not include food-based biofuel—however, this in itself might be seen as an optimistic projection given that, judging by current policies, the food-based biofuel sector will be a significant energy source in 2020[l]. Land-use change is an issue not only for food-based fuels but for any cropping system that competes for fertile agricultural land, and that reiterates the point made above that there is simply not enough confidence about either the likely volumes of future biofuel supply or the likely carbon intensities that may be achieved to incorporate biofuels into this analysis at this juncture.

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[l] This may change, and the European Union is considering a draft proposal to phase out governmental support for food-based biofuels after 2020.

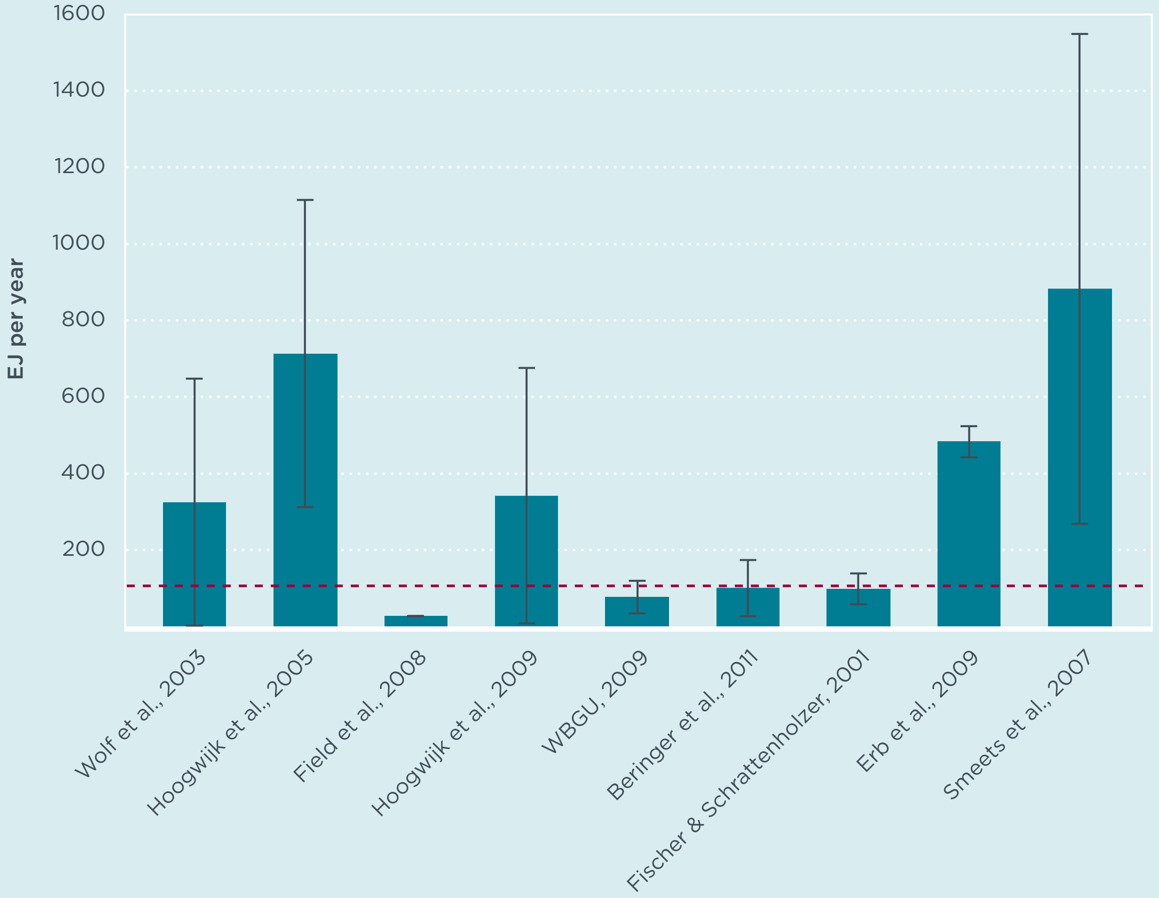

FIGURE 30. Literature Estimates of Bioenergy Potential in 2050[m]

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[m] Error bars show the range of the scenarios given; the solid color bars show the averages of scenario estimates. The dotted line shows the ICCT estimate of the maximum possible bioenergy potential in 2050.

APPENDIX D. MODE SHIFT AND ACTIVITY REDUCTION STRATEGIES

These push and pull strategies fall under the following categories: land-use planning, travel demand management (TDM), sustainable transportation infrastructure, logistics improvements, and fiscal measures.

LAND-USE PLANNING

Land-use planning regulations could reverse development trends worldwide that tend toward sprawl but especially in developing cities, where the decentralization of populations is rapidly increasing. By redirecting spending to promote compact, mixed-used development in transit-dependent areas and by adopting supportive TDM strategies, the average distance of personal vehicular trips can be reduced and nonmotorized mobility encouraged. Smart growth, which promotes concentration in compact city centers to limit sprawl, includes a combination of urban concepts such as walkable communities and transit-oriented development (TOD).

CA SB 375

Signed into law in 2008, California's Senate Bill 375 directs the state Air Resources Board to set regional targets for reducing GHG emissions. The new law establishes a "bottom up" approach to ensure that local governments are involved in the development of regional plans to achieve those targets. The law requires each metropolitan planning organization (MPO) to prepare a Sustainable Communities Strategy (SCS) as part of the Regional Transportation Plan (RTP), which establishes a vision for growth for the region, building on the existing planning framework to mesh the regional allocation of housing needs and regional transportation planning in an effort to reduce GHG emissions from motor vehicle trips. The SCS is the blueprint by which the region will meet its GHG emission reductions target if there is a feasible way to do so. Approved 2035 targets range from a 1 percent per capita increase in one of the smallest MPO regions to a 16 percent decrease per capita in one of the larger metro areas, relative to 2005 levels.[116]

Strategies include developing a comprehensive bicycle and pedestrian network; implementing "Complete Streets" plans within and between cities and to transit and school facilities; doubling the number of homes and jobs within half a mile of transit; and expanding carpool and tele-work incentive programs.[117,118]

TRAVEL DEMAND MANAGEMENT

Travel demand management policies such as parking restrictions, road pricing, and congestion charging schemes can help support the reduction in travel demand and encourage the shift to less energy-intensive modes. Some of the most comprehensive transportation policies that include TDM projects can be seen in London's congestion pricing scheme and Stockholm's congestion charge. Policies to curb the growth in private vehicle ownership rates also have been implemented in many countries around the world, including vehicle quota systems, license plate restrictions, and residential building parking requirements. Some of the more successful vehicle quota systems in place today are found in Singapore and Shanghai. These policies ensure that current and potential vehicle owners understand and internalize the true costs of private vehicle ownership, including but not limited to GHG and local air pollutant emissions.

LONDON CONGESTION PRICING AND PARKING SCHEME

Congestion pricing (also known as road user charges) refers to charging for use of roadways during peak hours in an effort to relieve congestion and promote alternative modes of transportation. Congestion pricing has been coming into more widespread use and is now applied in Singapore, half a dozen Norwegian cities, Stockholm, London, Milan, and on dozens of individual bridges and tunnels. When introduced in a way that improves travel reliability, cuts traffic delays, and boosts travel options, congestion pricing has won wide popular support, after initial skepticism. Prior to implementation of the congestion-pricing scheme, central London's roads were heavily congested. Travel costs had increased, and average speeds were below 11 mph (half of vehicle time in central London was spent waiting in traffic).

The London congestion-pricing program started in 2003 and originally covered the 21-square-kilometer central business district. (A western expansion of an additional 20 square km was implemented in 2007 but then removed in 2011.) Users pay a flat fee to enter the charging zone during peak periods. After the first year of implementation, traffic was reduced both inside and outside the zone; traffic delays decreased, and travel time reliability increased.[119]

VEHICLE LICENSE RESTRICTION IN CHINESE CITIES

A method of controlling the growth of vehicle ownership is limiting the number of license plates. The most notable approaches are vehicle plate auctions in Shanghai and the vehicle plate lottery in Beijing. Started in 1994, Shanghai's monthly auction system gives car registration rights to the highest bidders. In September 2012, the average bid for one of the 9,500 monthly license plates offered was a record RMB 66,425 (U.S. $10,533).[120] Beijing's private car quota began in 2011. In contrast to Shanghai's system, Beijing offers license plates at no cost but requires car buyers to enter a lottery from which license plate winners are selected each month. As of September 2012, there were more than 1.1 million Beijing residents entered in the lottery hoping for one of each month's 20,000 plates offered.[121] Following Shanghai and Beijing, other cities in China are currently developing and beginning to implement restrictions on the increase in number of vehicles. For example, Guangzhou has recently put into practice a hybrid license plate lottery/auction system designed to reduce annual vehicle sales by two-thirds.

SUSTAINABLE TRANSPORTATION INFRASTRUCTURE

Shifting travel and transportation activity to public transit, passenger rail, nonmotorized means, freight rail, and inland waterways dramatically improves the energy efficiency of transportation systems. In the near term, there are many opportunities to promote mode shift in relatively dense urban areas by enhancing public transportation and nonmotorized infrastructure. Investments in high-quality rail and bus networks between major cities, reliance on higher road user charges, and reduced investment in high-speed motorway networks can also reduce growth in intercity travel. Investments in high-speed rail, if well designed, can curb the growth in short- to moderate-distance aviation routes as well. Shifting freight away from roads requires additional infrastructure, modernization and expansion of freight railways and inland waterways, and investment in efficient intermodal centers, as well as effective pricing and road user charging for the movement of goods.

BUS RAPID TRANSIT

Bus rapid transit (BRT) is a mass transit system that combines the efficiencies and quality of rail systems with the flexibility and relative low cost of buses while producing significant environmental benefits. BRT offers levels of speed, capacity, and passenger comfort and convenience comparable to rail-based systems but can be built at a fraction of the cost and construction time. The journey on BRT is much quicker than on a regular bus because BRTs utilize bus-only lanes and passengers pay at the station rather than on the bus. As a result, many countries are implementing BRT systems.

In 2005, Mexico City opened Metrobus, a BRT corridor along one of the city's busiest streets. Metrobus replaced about 350 standard buses with 97 new articulated BRT vehicles. Some of the BRT vehicles are owned by a private company, CISA, and some are owned by a public company, RTP. Vehicles have a maximum capacity of 160 passengers and run at extremely high frequencies, roughly 56 per peak hour along the northern half of the route. Currently, the BRT is carrying roughly 250,000 passengers per day. A trust fund was set up to manage, invest, and distribute all fare revenues. The trust fund contracts directly with a fare collection agent, which, among other things, provides fare collection equipment, sells smart cards, collects the cash, and deposits cash with the trust fund. Mexico City has built four Metrobus corridors and a new subway line, and more than two-dozen BRT systems are being planned or are under construction across Mexico. BRT systems have been developed in well in excess of 100 cities worldwide—including Guangzhou, Ahmedabad, Tehran, Cape Town, Rio de Janeiro, and Brisbane—at an accelerating rate in recent years.[122]

LOGISTICS IMPROVEMENTS

In addition to shifting loads from trucks to freight rail, policies can also be implemented to improve the freight industry's logistics efficiency. Policy options for improving logistics are often tied to fiscal measures. Truck road charging, for example, could result in higher truck efficiency through better capacity utilization, more efficient routing, and reduction of empty-payload mileage. Improved logistics systems and the introduction of regional freight distribution centers may facilitate transfers from half-empty large trucks to full small trucks (helping minimize the circulation of half-empty loads) and increase overall capacity utilization of truck and rail vehicles. Optimizing vehicle loads can cut freight costs and support sustainable transportation system goals. Opportunities for improved logistics are especially significant in countries like China and India, where a large share of trucking now uses monobody trucks, which must run empty much of the time searching for their next load. As these nations modernize their trucking industries, they have the chance to adopt drop-and-hook tractor-trailer technology, which, together with better information, communications, and pricing incentives, can increase truck load factors and overall system efficiency. Transportation mitigation potential is not analyzed specifically in this report but will be evaluated more fully in future studies.

EU MARCO POLO PROGRAM

Marco Polo is the EU program aimed at relieving road congestion and reducing associated pollution by shifting freight movement from the road to more efficient transportation modes.

Between 2003 and 2009, 125 projects involving more than 500 companies have received funding from the first Marco Polo program. Regulation (EC) No 1692/2006 extended the program as well as the geographic area. Begun in 2007, Marco Polo II is attempting to shift 20 billion metric ton-kilometers of freight annually from heavy-duty trucks to rail. The program, to be carried out until 2013, will translate into a nearly 1 percent mode shift per year after a total program investment of €450 million (U.S. $570 million).

FISCAL MEASURES

There are a variety of fiscal measures—taxes, fees, and other incentives—that can boost overall transportation system efficiency. All regions currently use fiscal measures to support transportation sector goals and planning to some degree or another. Directly linking fiscal measures to system efficiency or carbon reduction will help to avoid perverse incentives and will be conducive of more rapid progress toward these goals. “Feebates” can reinforce efficiency standards, or even replace such standards with high enough fee and rebate levels. Market-based measures such as emission trading schemes or carbon taxes can help drive demand for lower-carbon fuels and modes. Pricing of road use can reduce overall transportation activity, support a shift to more sustainable modes, and in some cases even result in improved in-use vehicle efficiency as a result of better traffic flow conditions. Furthermore, fiscal measures can help to fund the transportation infrastructure and services that are needed to support an increased share for less carbon-intensive modes.

Fuel taxes vary widely from country to country. Figure 31 provides average gasoline and diesel fuel prices in 2010 across the main countries highlighted in this report. Because data on fuel taxes are difficult to collect, fuel prices are used as a proxy for taxation levels, acknowledging that such a proxy is not perfect since refining and distribution costs vary among countries. Higher levels of fuel taxation in the EU-27 are one of the constraints that led to a more efficient passenger vehicle fleet, lower levels of private car activity, and the maintenance of higher mode shares for rail and public transportation. Japan, Brazil, and South Korea also have high fuel prices relative to other regions. The United States has the lowest levels of gasoline prices among the regions included in this analysis, although Mexico and India both have lower diesel prices. China, India, and Mexico all continue to stabilize fuel prices, which means subsidizing fuel when market prices are relatively high.

FIGURE 31. Fuel Prices By Country

Greater reductions result when push and pull strategies are combined. In central London, congestion pricing paired with improvements in public transportation led to a 15 percent decrease in traffic.[123] Implementing parking pricing schemes led to further declines.[124]

Each of the policy strategies outlined above can be made more effective by well-designed fiscal measures. For example, higher fuel prices/taxes support all three elements of the Avoid-Shift-Improve framework, serving to reduce overall transportation activity, make less carbon-intensive modes more attractive by altering the operating cost differential between modes, and increase consumer demand for more efficient vehicles. Repricing of existing user fees for drivers can also boost energy efficiency. For example, by shifting from fixed-price, term-based car insurance to pay-by-the-mile or use-based insurance, jurisdictions can expect to see a reduction in LDV distance traveled on the order of 8–10 percent while providing the majority of drivers with significant cost savings. Such pricing strategies are coming into more widespread use in the United States, Europe, and other regions.

APPENDIX E. BASELINE DATA OVERVIEW

PPP-GDP (billion 2005 USD)

Region	2000	2005	2010	2015	2020	2025	2030
United States	11,226	12,638	13,145	14,800	16,542	18,353	20,363
Canada	1,002	1,132	1,194	1,406	1,620	1,825	2,056
Mexico	1,179	1,298	1,368	1,611	1,856	2,091	2,355
Brazil	1,392	1,585	1,880	2,298	2,743	3,195	3,722
Rest of Latin America	1,609	1,874	2,294	2,791	3,290	3,759	4,295
EU-27	11,918	13,072	13,542	15,024	16,507	17,959	19,538
Russia	1,267	1,698	1,960	2,396	2,859	3,331	3,880
Rest of Europe	894	1,103	1,250	1,550	1,863	2,171	2,529
China	3,598	5,557	8,926	14,052	19,434	23,531	28,492
Japan	3,625	3,873	3,864	4,245	4,562	4,795	5,039
India	1,718	2,358	3,408	5,031	7,007	9,202	12,083
South Korea	875	1,097	1,271	1,541	1,766	1,910	2,066
Australia	582	673	756	917	1,051	1,137	1,230
Rest of Asia-Pacific	2,950	3,731	4,547	6,112	7,770	9,336	11,217
Middle East	2,347	3,010	3,644	4,498	5,485	6,610	7,964
Africa	1,347	1,747	2,186	2,857	3,501	4,020	4,615
Global	**47,527**	**56,446**	**65,234**	**81,131**	**97,858**	**113,223**	**131,444**

POPULATION (million)

Region	2000	2005	2010	2015	2020	2025	2030
United States	282	297	310	324	337	350	362
Canada	31	32	34	36	37	39	40
Mexico	100	106	113	120	126	131	135
Brazil	174	186	195	203	210	216	220
Rest of Latin America	242	259	276	294	310	326	340
EU-27	481	491	500	506	511	514	516
Russia	147	144	143	142	141	139	136
Rest of Europe	115	113	112	111	111	109	108
China	1,269	1,308	1,341	1,370	1,388	1,395	1,393
Japan	126	126	127	126	125	123	120
India	1,054	1,140	1,225	1,308	1,387	1,459	1,523
South Korea	46	47	48	49	50	50	50
Australia	19	20	22	24	25	27	28
Rest of Asia-Pacific	957	1,031	1,100	1,173	1,242	1,305	1,362
Middle East	297	329	365	398	429	459	486
Africa	736	828	930	1,044	1,168	1,300	1,437
Global	**6,076**	**6,457**	**6,843**	**7,228**	**7,597**	**7,941**	**8,257**

BASELINE TOTAL TRANSPORTATION GHG EMISSIONS BY REGION

TRANSPORTATION GHG EMISSIONS ($MtCO_2e$) – INCLUDES AVIATION							
Region	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
United States	2,264	2,358	2,315	2,523	2,750	2,977	3,217
Canada	211	207	215	236	259	280	304
Mexico	126	140	167	190	216	241	272
Brazil	221	234	283	308	341	379	429
Rest of Latin America	181	203	255	295	340	384	439
EU-27	1,327	1,375	1,441	1,534	1,643	1,763	1,898
Russia	238	263	294	331	379	433	496
Rest of Europe	169	214	223	251	286	323	374
China	542	825	1,302	1,634	2,069	2,430	2,897
Japan	431	397	364	357	354	352	352
India	191	254	382	574	790	995	1,241
South Korea	114	130	149	188	217	234	253
Australia	104	118	123	134	143	149	156
Rest of Asia-Pacific	331	432	506	576	669	770	908
Middle East	151	206	305	381	474	586	730
Africa	223	261	288	322	359	393	436
International	845	931	1,003	1,191	1,260	1,447	1,649
Global	**7,668**	**8,548**	**9,615**	**11,023**	**12,548**	**14,135**	**16,053**

VEHICLE ACTIVITY BY MODE AND REGION

ANNUAL LDV ACTIVITY (billion vehicle-km)							
Region	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
United States	4,059	4,430	4,251	4,768	5,272	5,762	6,263
Canada	285	303	328	380	429	472	520
Mexico	141	197	285	335	387	437	497
Brazil	304	326	431	514	605	688	789
Rest of Latin America	202	215	273	328	385	437	500
EU-27	2,615	2,824	2,881	3,063	3,294	3,522	3,773
Russia	254	313	400	513	649	788	944
Rest of Europe	227	256	286	356	431	508	617
China	185	411	993	1,452	2,080	2,554	3,147
Japan	698	690	616	629	636	637	635
India	52	94	169	326	561	828	1,186
South Korea	142	169	184	249	300	327	358
Australia	139	154	173	214	244	261	280
Rest of Asia-Pacific	176	250	362	453	557	662	804
Middle East	213	286	390	502	639	803	1,015
Africa	154	183	208	242	274	297	325
Global	**9,846**	**11,100**	**12,231**	**14,323**	**16,742**	**18,985**	**21,651**

ANNUAL BUS ACTIVITY (billion vehicle-km)

Region	2000	2005	2010	2015	2020	2025	2030
United States	21	21	25	26	26	27	28
Canada	3	3	3	3	4	4	4
Mexico	13	14	15	17	18	20	21
Brazil	27	26	26	26	25	27	28
Rest of Latin America	28	36	50	54	58	62	67
EU-27	34	35	34	36	35	35	35
Russia	14	19	25	28	28	27	26
Rest of Europe	20	22	25	26	28	29	29
China	197	193	224	261	306	348	406
Japan	7	7	6	5	5	5	4
India	39	48	62	95	129	154	177
South Korea	33	39	45	49	52	54	55
Australia	2	2	2	2	2	2	2
Rest of Asia-Pacific	81	104	122	129	138	147	159
Middle East	17	23	41	48	57	66	77
Africa	62	70	77	83	89	95	102
Global	**598**	**663**	**784**	**889**	**1,001**	**1,101**	**1,219**

ANNUAL MOTORCYCLE ACTIVITY (billion vehicle-km)

Region	2000	2005	2010	2015	2020	2025	2030
United States	17	17	30	19	20	22	24
Canada	2	2	3	3	4	4	4
Mexico	3	6	12	14	16	18	20
Brazil	26	46	100	112	121	131	144
Rest of Latin America	41	59	113	131	149	166	187
EU-27	99	113	110	205	227	250	275
Russia	28	29	33	40	48	57	66
Rest of Europe	14	13	17	20	24	28	32
China	463	869	1,379	1,789	2,405	2,875	3,365
Japan	68	63	61	61	60	60	59
India	379	567	855	1,347	1,885	2,314	2,754
South Korea	4	6	6	8	10	10	11
Australia	2	2	2	2	2	2	3
Rest of Asia-Pacific	357	545	794	878	1,014	1,152	1,337
Middle East	11	15	23	29	36	45	55
Africa	20	30	38	42	46	50	54
Global	**1,533**	**2,381**	**3,575**	**4,700**	**6,069**	**7,184**	**8,388**

ANNUAL TRUCK ACTIVITY (billion vehicle-km)

Region	2000	2005	2010	2015	2020	2025	2030
United States	388	422	516	552	589	624	661
Canada	81	84	89	95	100	105	110
Mexico	74	76	80	91	103	115	129
Brazil	74	74	82	79	81	88	96
Rest of Latin America	102	111	146	174	203	231	263
EU-27	431	503	695	726	759	811	847
Russia	87	101	104	108	112	117	122
Rest of Europe	63	88	118	128	140	152	166
China	240	298	470	602	722	814	930
Japan	262	243	228	228	225	220	215
India	62	86	143	232	334	422	518
South Korea	44	34	54	88	114	130	147
Australia	44	53	55	58	60	62	63
Rest of Asia-Pacific	177	219	262	317	379	440	519
Middle East	68	96	161	206	260	322	402
Africa	139	164	184	210	235	256	280
Global	**2,335**	**2,653**	**3,388**	**3,893**	**4,416**	**4,908**	**5,468**

ANNUAL PASSENGER RAIL ACTIVITY (billion passenger-km)

Region	2000	2005	2010	2015	2020	2025	2030
United States	48	50	58	61	65	68	70
Canada	2	1	1	2	2	2	2
Mexico	0	0	1	1	1	1	1
Brazil	0	0	0	0	0	0	1
Rest of Latin America	8	8	9	10	11	11	12
EU-27	448	459	476	508	538	564	591
Russia	239	229	201	253	312	371	436
Rest of Europe	110	126	143	159	175	190	206
China	453	522	719	842	1,003	1,126	1,266
Japan	384	391	394	382	369	357	342
India	434	535	776	1,200	1,646	1,984	2,312
South Korea	49	54	59	66	71	73	75
Australia	11	12	12	14	15	16	17
Rest of Asia-Pacific	169	199	243	265	291	318	353
Middle East	13	16	18	22	27	32	38
Africa	18	20	23	25	28	29	32
Global	**2,386**	**2,623**	**3,133**	**3,810**	**4,552**	**5,142**	**5,755**

ANNUAL FREIGHT RAIL ACTIVITY (billion tonne-km)

Region	2000	2005	2010	2015	2020	2025	2030
United States	2,255	2,519	2,258	2,409	2,565	2,722	2,892
Canada	323	352	300	317	335	352	371
Mexico	28	32	36	40	44	47	52
Brazil	155	221	297	304	317	334	358
Rest of Latin America	69	72	80	88	97	107	118
EU-27	502	499	436	430	432	433	435
Russia	1,321	1,838	1,864	1,936	2,018	2,105	2,208
Rest of Europe	166	200	231	252	275	299	327
China	1,351	1,946	2,736	2,936	3,387	3,781	4,302
Japan	22	23	21	21	21	21	20
India	316	455	669	993	1,303	1,515	1,687
South Korea	11	12	9	14	19	21	24
Australia	137	189	226	239	250	256	263
Rest of Asia-Pacific	546	683	828	880	943	1,010	1,093
Middle East	30	34	41	51	61	75	91
Africa	109	123	145	155	168	180	194
Global	**7,340**	**9,200**	**10,178**	**11,067**	**12,236**	**13,259**	**14,435**

ANNUAL AVIATION ACTIVITY (billion revenue passenger-km)

Region	2000	2005	2010	2015	2020	2025	2030
Global	**3,037**	**3,924**	**4,602**	**5,629**	**6,866**	**8,434**	**10,665**

VEHICLE STOCK BY MODE AND REGION

LDV STOCK (million vehicles)

Region	2000	2005	2010	2015	2020	2025	2030
United States	212.7	231.9	230.5	240.4	264.4	277.4	291.0
Canada	15.2	16.6	18.6	21.8	24.7	27.3	30.2
Mexico	10.2	14.3	21.6	31.6	37.3	43.1	49.9
Brazil	17.8	21.0	28.2	33.3	41.4	54.4	64.3
Rest of Latin America	14.0	15.2	19.6	24.6	29.9	35.0	41.3
EU-27	200.9	220.2	238.8	239.0	260.9	284.6	308.8
Russia	20.4	25.6	33.7	51.7	67.9	85.3	105.0
Rest of Europe	20.0	23.5	28.1	30.8	38.8	47.5	59.6
China	8.5	19.2	58.6	75.2	136.8	201.9	265.5
Japan	52.4	57.1	58.3	55.3	55.9	56.0	55.8
India	6.1	10.3	14.8	28.5	49.0	72.3	103.5
South Korea	9.2	12.2	14.7	17.0	20.7	22.8	25.1
Australia	9.7	10.7	12.4	14.7	16.9	18.1	19.4
Rest of Asia-Pacific	21.1	29.3	40.1	50.6	64.4	79.9	101.8
Middle East	11.4	16.3	25.6	30.4	40.1	51.9	67.4
Africa	14.4	17.8	21.0	24.4	27.6	29.9	32.7
Global	**644.0**	**741.1**	**864.6**	**969.3**	**1,176.7**	**1,387.5**	**1,621.4**

BUS STOCK (million vehicles)							
Region	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
United States	0.8	0.9	0.9	0.8	0.9	0.9	0.9
Canada	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Mexico	0.2	0.3	0.4	0.3	0.4	0.4	0.4
Brazil	0.2	0.3	0.3	0.4	0.4	0.4	0.4
Rest of Latin America	0.6	0.8	1.2	1.1	1.2	1.2	1.3
EU-27	0.8	0.8	0.8	1.1	1.1	1.1	1.1
Russia	0.6	0.8	0.9	0.7	0.7	0.7	0.7
Rest of Europe	0.4	0.4	0.5	0.4	0.5	0.5	0.5
China	2.0	2.1	2.6	2.4	2.8	3.1	3.5
Japan	0.2	0.2	0.2	0.2	0.2	0.2	0.1
India	0.5	0.5	0.7	1.1	1.4	1.7	2.0
South Korea	1.4	1.7	1.9	2.1	2.3	2.3	2.4
Australia	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rest of Asia-Pacific	1.6	2.2	2.6	2.6	2.8	2.9	3.2
Middle East	0.3	0.5	0.9	1.0	1.1	1.3	1.5
Africa	1.3	1.5	1.6	1.7	1.8	1.9	2.0
Global	**11.2**	**13.1**	**15.6**	**16.1**	**17.6**	**18.9**	**20.3**

MOTORCYCLE STOCK (million vehicles)							
Region	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
United States	4	6	8	7	8	8	9
Canada	0	0	1	1	1	1	1
Mexico	0	1	1	2	2	3	3
Brazil	3	6	11	13	14	16	17
Rest of Latin America	5	6	13	15	17	18	21
EU-27	23	30	35	35	38	42	46
Russia	6	6	6	13	16	19	22
Rest of Europe	5	4	6	7	8	9	11
China	38	76	100	179	240	287	336
Japan	14	13	12	12	12	12	12
India	32	50	76	120	169	207	246
South Korea	2	2	2	2	2	2	2
Australia	0	0	1	0	0	1	1
Rest of Asia-Pacific	54	85	135	158	183	209	244
Middle East	2	2	3	4	5	6	8
Africa	4	6	7	8	9	10	11
Global	**192**	**293**	**417**	**576**	**726**	**850**	**989**

TRUCK STOCK (million vehicles)							
Region	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
United States	8	8	11	11	12	12	13
Canada	3	3	3	3	4	4	4
Mexico	2	2	3	4	5	5	6
Brazil	1	1	1	3	3	3	4
Rest of Latin America	5	5	7	8	10	11	13
EU-27	27	31	34	38	40	43	45
Russia	4	5	5	6	6	7	7
Rest of Europe	4	5	6	6	6	7	8
China	7	10	14	13	16	18	20
Japan	19	18	16	19	19	19	18
India	2	2	4	6	9	11	14
South Korea	3	3	3	4	5	6	7
Australia	2	3	3	3	3	3	3
Rest of Asia-Pacific	9	12	16	17	20	23	27
Middle East	2	3	6	8	10	12	15
Africa	6	7	9	10	11	12	13
Global	**104**	**119**	**141**	**159**	**177**	**196**	**216**

LIST OF ACRONYMS

A-S-I	Avoid-Shift-Improve
AFE	Average Fuel Economy (South Korea)
ANP	Petroleum National Agency
ARB	Air Resources Board (California)
BEV	Battery Electric Vehicle
BRT	Bus Rapid Transit
CAFC	Corporate Average Fuel Consumption (Canada)
CAFE	Corporate Average Fuel Economy (United States)
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
DNV	Det Norske Veritas
EC	European Commission
EEDI	Energy Efficiency Design Index
EGR	Exhaust Gas Recirculation
EIS	Entry into Service
EPA	Environmental Protection Agency (United States)
ETS	Emission Trading Scheme
EU	European Union
EU-27	European Union (27 member states)
EV	Electric Vehicle
FAO	Food And Agriculture Organization of the United Nations
FCEV	Fuel Cell Electric Vehicle
FYP	Five Year Plan (China)
GDP	Gross Domestic Product
GFEI	Global Fuel Economy Initiative
GHG	Greenhouse Gas Emissions
GIZ	German Society for International Cooperation
$GtCO_2e$	Gigatons of CO_2 Equivalent
GWP	Global Warming Potential
HDT	Heavy-Duty Trucks
HDV	Heavy-Duty Vehicle
ICAO	International Civil Aviation Organization
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
IEA	International Energy Agency
IEEC	International Energy Efficiency Certification
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
iMarEST	Institute of Marine Engineering, Science and Technology
IMF	International Monetary Fund
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPTA	International Parcel Tankers Association
ITDP	Institute for Transportation and Development Policy
ITF	International Transport Forum
km/L	Kilometer per Liter
L/100km	Liters per 100 Kilometers
LCV	Light Commercial Vehicles
LDV	Light-Duty Vehicle
LLGHG	Long-Lived Greenhouse Gas Emissions
LNG	Liquefied Natural Gas

LPG	Liquefied Petroleum Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MBM	Market-Based Mechanisms
Mboe	Million Barrels of Oil Equivalent
MDIC	Ministry of Development Industry and Commerce (Brazil)
MEPC	Marine Environment Protection Committee
MJ	Megajoule
MoMo	Mobility Model
mpg	Miles per Gallon
MPO	Metropolitan Planning Organization
$MtCO_2e$	Million metric tons of CO_2 Equivalent
MY	Model Year
N_2O	Nitrous Oxide
NAS	National Academy of Sciences
NEDC	New European Driving Cycle
NHTSA	National Highway Traffic Safety Administration
NMT	Nonmotorized Transportation
NO_x	Nitrogen Oxides
O_3	Ozone
OECD	Organisation for Economic Co-Operation and Development
PHEV	Plug-in Hybrid Electric Vehicle
$PM_{2.5}$	Particulate Matter with Diameter of 2.5 Micrometers or Less
PM_{10}	Particulate Matter with Diameter of 10 Micrometers or Less
PSL	Port State Levy
PV	Passenger Vehicle
RF	Radiative Forcing
RFS	Renewable Fuel Standard
RM	Rebate Mechanism
RO	Recognized Organization
Ro-Ro	Roll-on Roll-off
RTP	Regional Transportation Plan
SCR	Selective Catalytic Reduction
SCS	Sustainable Communities Strategy (California)
SECT	Ship Efficiency and Credit Trading
SEEMP	Ship Energy Efficiency Management Plan
SO_2	Sulfur Dioxide
SUV	Sport Utility Vehicles
TDM	Travel Demand Management
TEU	Twenty-foot Equivalent Unit
TOD	Transit-Oriented Development
TTW	Tank-to-Wheel
UN HLTF	United Nations High-Level Task Force
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
U.S.	United States
WFP	United Nations World Food Programme
WG	International Maritime Organization Expert Working Group
WTO	World Trade Organization
WTT	Well-to-Tank
WTW	Well-to-Wheel
ZEV	Zero-Emission Vehicle

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