Chapter 7. Transportation

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KEY FINDINGS

- The transportation sector of North America released 2120 Mt of CO_2 into the atmosphere in 2003, 37% of the total CO_2 emissions from worldwide transportation activity and about 22% of total global CO_2 emissions.
- Transportation energy use in North America and the associated CO_2 emissions have grown substantially and relatively steadily over the past 40 years. Growth has been most rapid in Mexico, the country most dependent upon road transport.
- Carbon emissions by transport are determined by the levels of passenger and freight activity, the shares of transport modes, the energy intensity of passenger and freight movements, and the carbon intensity of transportation fuels. The growth of passenger and freight activity is driven by population, per capita income, and economic output.
- Chiefly as a result of economic growth, energy use by North American transportation is expected to increase by 46% from 2003 to 2025. If the mix of fuels is assumed to remain the same, carbon dioxide emissions would increase from 2151 Mt CO_2 in 2003 to 3149 Mt CO_2 in 2025. Canada, the only one of the three countries in North America to have committed to specific GHG reduction goals, is expected to show the lowest rate of growth in CO_2 emissions.
- The most widely proposed options for reducing the carbon emissions of the North American transportation sector are increased vehicle fuel economy, increased prices for carbon fuels, liquid fuels derived from biomass, and in the longer term, hydrogen produced from renewables, nuclear energy, or from fossil fuels with carbon sequestration. Biomass fuels appear to be a promising near- and long-term option, while hydrogen could become an important energy carrier after 2025.
- After the development of advanced energy efficient vehicle technologies and low-carbon fuels, the most pressing research need in the transportation sector is for comprehensive, consistent, and rigorous assessments of carbon emissions mitigation potentials and costs for North America. There is also a need for improved data, particularly the provision of data to complete the country-specific histories of emissions from transportation, and a consistent description of the accuracy of each country's data.

Transportation is the largest source of carbon emissions among North American energy end uses. This fact reflects the vast scale of passenger and freight movements in a region that comprises one-fourth of the global economy, as well as the dominance of relatively energy-intensive road transport and the near total dependence of North American transportation systems on petroleum as a source of energy. If present trends continue, carbon emissions from North American transportation are expected to increase by more than one-half by 2050. Options for mitigating carbon emissions from the transportation sector like increased vehicle fuel economy and biofuels could offset the expected growth in transportation activity. However, at present only Canada has committed to achieving a specific reduction in future greenhouse gas emissions: 6% below 1990 levels by 2012 (Government of Canada, 2005).

INVENTORY OF CARBON EMISSIONS

Worldwide, transportation produced about 22% (5.36 Gt yr^{-1}) of total global carbon dioxide emissions from the combustion of fossil fuels (24.2 Gt CO_2) in 2000 (page 3-1 in U.S. EPA, 2005; Marland, Boden and Andres, 2005). Home to 6.7% of the world's 6.45 billion people and source of 24.8% of the world's $55.5 trillion gross world product (CIA, 2005), North America produces 37% (an estimated 2120 Mt CO_2 in 2005) of the total carbon emissions from worldwide transportation activity (an estimated 5846 Mt CO_2 in 2005) (Fulton and Eads, 2004).

Transportation activity is driven by population, economic wealth, and geography. Of the approximately 435 million residents of North America, 68.0% reside in the United States, 24.5% in Mexico, and 7.5% in Canada. The differences in the sizes of the three countries' economies are far greater. The United States is the world's largest economy, with an estimated gross domestic product (GDP) of $11.75 trillion in 2004. Although Mexico has approximately three times the population of Canada, its GDP is roughly the same, $1.006 trillion compared to $1.023 trillion (measured in 2004 purchasing power parity dollars). With the largest population and largest economy, the United States has by far the largest transportation system. The United States accounted for 87% of the energy used for transportation in North America in 2003, Canada for 8%, and Mexico 5% (Fig. 7-1) (see Table 4-1 in NATS, 2005). These differences in energy use are reflected in carbon dioxide emissions from the North American transportation sector (Table 7-1).

Figure 7-1. Transportation energy use in North America, 1990–2003.

Table 7-1. Carbon dioxide emissions from transportation in North America in 2003.

Transportation is defined as private and public vehicles that move people and commodities (U.S. EPA, 2005, p. 296). This includes automobiles, trucks, buses, motorcycles, railroads and railways (including streetcars and subways), aircraft, ships, barges, and natural gas pipelines. This definition excludes petroleum, coal slurry, and water pipelines, as well as the transmission of electricity, although many countries consider pipelines part of the transport sector. It also generally excludes mobile sources not engaged in transporting people or goods, such as construction equipment, and on-farm agricultural equipment. In addition, carbon emissions from international bunker fuel use in aviation and waterborne transport, though considered part of transport emissions, are generally accounted for separately from a nation's domestic greenhouse gas inventory. In this chapter, upstream, or well-to-tank, carbon emissions are not included with transportation end-use, nor are end-of-life emissions produced in the disposal or recycling of materials used in transportation vehicles or infrastructure. These two categories of emissions typically comprise 20–30% of total life cycle emissions for transport vehicles (see Table 5.4 in Weiss *et al.*, 2000). In the future, it is likely that upstream carbon emissions will be of greater importance in determining the total emissions due to transportation activities.

In addition to carbon dioxide, the combustion of fossil fuels by transportation produces other greenhouse gases including methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (VOCs). Those containing carbon are generally oxidized in the atmosphere to ultimately produce CO_2. However, the quantities of non-CO_2 gases produced by transportation vehicles are minor in comparison to the volume of CO_2 emissions. For example, in the United States, mobile sources including international bunker fuels produced only 132,000 Mt CH_4 (or 2.8 Mt CO_2 equivalents) in 2003. This is a tiny fraction of the 1770.4 Mt of CO_2 emitted by the transportation sector (see Tables 2-3, 2-4, and 2-7 in U.S. EPA, 2005). This chapter will therefore address only the carbon dioxide emissions from transportation activities.

Fuels Used in Transportation

Virtually all of the energy used by the transport sector in North America is derived from petroleum, and most of the remainder comes from natural gas (Table 7-2). In the United States, 96.3% of total transportation energy is obtained by combustion of petroleum fuels (U.S. DOE/EIA, 2005a). Most of the non-petroleum energy is natural gas used to power natural gas pipelines (2.5%, 744 PJ). During the past two decades, ethanol use as a blending component for gasoline has increased from a negligible amount to 1.1% of transportation energy use (312 PJ). Electricity, mostly for passenger rail transport, comprises only 0.1% of U.S. transport energy use. This pattern of energy use has persisted for more than half a century (Fig. 7-1).

Table 7-2. Summary of North American transport energy use and carbon dioxide emissions in 2003 by fuel type.

The pattern of energy sources is only a little different in Mexico where 96.2% of transportation energy use is gasoline, diesel, or jet fuel: 3.4% is liquefied petroleum gas (LPG), and less than 0.2% is electricity (Rodríguez, 2005). In Canada, natural gas use for natural gas pipelines accounts for 7.5% of transport energy use, 91.8% is petroleum, 0.5% is propane (LPG) and only 0.1% is electricity (see Table 1 in NRCan, 2006).

Mode of Transportation

Mode of transportation refers to how people and freight are moved about, whether by road, rail, or air, in light or heavy vehicles. Carbon dioxide emissions from the North American transportation sector are summarized by mode in Table 7-3, and the distribution of emissions by mode for North America in 2003 is illustrated in Fig. 7-2.

Table 7-3. Summary of North American transport energy use and carbon dioxide emissions in 2003 by fuel type

Figure 7-2. North American carbon emissions from transportation by mode, 2003.

Freight Transport

Movement of freight is a major component of the transportation sector in North America. Total freight activity in the United States, measured in metric ton-km, is 20 times that in Mexico and more than 10 times the levels observed in Canada (Figs. 7-3a, 7-3b, 7-3c).

Figure 7-3a, 7-3b, and 7-3c. Freight activity by mode in Canada, Mexico, and the United States.

In Mexico, trucking is the mode of choice for freight movements. Four-fifths of Mexican metric ton-km are produced by trucks. Moreover, trucking's modal share has been increasing over time.

In Canada, rail transport accounts for the majority of freight movement (65%). Rail transport is well suited to the approximately linear distribution of Canada's population in close proximity to the U.S. border, the long-distances from east to west, and the large volumes of raw material flows typical of Canadian freight traffic (see Table 5-2 in NATS, 2005).

In the United States, road freight plays a greater role than in Canada, and rail is less dominant, although rail still carries the largest share of metric ton-km (40%). In none of the countries does air freight account for a significant share of metric ton-km.

Passenger Transport

In all three countries, passenger transport is predominantly by road, followed in distant second by air travel. Nearly complete data are available for passenger-kilometers-traveled (pkt) by mode in the United States and Canada in 2001. Of the more than 8 trillion pkt accounted for by the United States, 88% was by light-duty personal vehicles, roughly equally split between passenger cars and light trucks (Fig. 7-4a) (motorcycle pkt, about 0.2% of the total, is included with passenger car). Air travel claims almost 9%; other modes are minor.

Figure 7-4a. Distribution of passenger travel in the United States by mode.

Canadian passenger travel exhibits a very similar modal structure, but with a smaller role played by light trucks and air and a large share for buses (Fig. 7-4b) (transit numbers for Canada were not available at the time these figures were compiled).

Figure 7-4b. Distribution of passenger travel by mode in Canada.

TRENDS AND DRIVERS

In all three countries, transportation energy use has grown substantially and relatively steadily. Figures 7-5a and 7-5b illustrate the evolution of transport energy use by mode for Mexico and the United States. Energy use has grown most rapidly in Mexico, the country most dependent on road transport. In the United States, the steady growth of transportation oil use was interrupted by oil price shocks in 1973–74, 1979–80, and to a much lesser degree in 1991. The impact of the attack on the World Trade Center in 2001 is also visible, especially with respect to energy use for air travel.

Figure 7-5a and 7-5b. Evolution of transport energy use in Mexico and the United States.

The evolution of transport carbon emissions has closely followed the evolution of energy use. Carbon dioxide emissions by mode are shown for the United States and Canada for the period 1990–2003 in Figs. 7-6a and 7-6b. The Canadian data include light-duty commercial vehicles in road freight transport, while all light trucks are included in the light-duty vehicle category in the U.S. data. These data illustrate the relatively faster growth of freight transport energy use. Fuel economy standards in both countries were effective in restraining the growth of passenger car and light-truck energy use (NAS, 2002). From 1990 to 2003 passenger kilometers traveled by road in Canada increased by 23%, while energy use increased by only 15%. In 2003, freight activity accounted for more than 40% of Canada's transport energy use. And while passenger transport energy use increased by 15% from 1990 to 2003, freight energy use increased by 40%. The Canadian transport energy statistics do not include natural gas pipelines as a transport mode.

Figure 7-6a and 7-6b. Transport CO_2 emissions in Canada and the United States, 1990–2003.

Carbon emissions by transport are determined by the levels of passenger and freight activity, the shares of transport modes, the energy intensity of passenger and freight movements, and the carbon intensity of transportation fuels. In North America, petroleum fuels supply over 95% of transportation's energy requirements and account for 98% of the sector's GHG emissions. Among modes, road vehicles are predominant, producing almost 80% of sectoral GHG emissions. As a consequence, the driving forces for transportation GHG emissions have been changes in activity and energy intensity. The principal driving forces of the growth of passenger transportation are population and per capita income (WBCSD, 2004). With rising per capita income comes increased vehicle ownership, use, fuel consumption, and emissions. In general, energy forecasters expect the greatest growth in vehicle ownership and fossil fuel use in transportation over the next 25–50 years to occur in the developing economies (U.S. DOE/EIA, 2005b; IEA, 2004; WBCSD, 2004; Nakićenović, Grűbler, McDonald, 1998). The chief driving forces for freight activity are economic growth and the integration of economic activities at both regional and global scales (WBCSD, 2004).

Population growth rates are similar in the three countries, 0.92% per year in the United States, 1.17% per year in Mexico, and 0.90% per year in Canada. Recent annual GDP growth rates are 4.4% for the United States, 4.1% for Mexico, and 2.4% for Canada (CIA, 2005). The U.S. Energy Information Administration's Reference Case assumes annual GDP growth rates of 3.1% for the United States, 2.4% for Canada, and 3.9% for Mexico (see Table A3 in U.S. DOE/EIA, 2005b). Assumed population growth rates are United States: 0.9%; Canada: 0.6%; Mexico: 1.0% (see Table A14 in U.S. DOE/EIA, 2005b).

Projections of North American transportation energy use and carbon emissions to 2030 have been published by the U.S. Energy Information Administration (U.S. DOE/EIA, 2005b) and the International Energy Agency (2005). Chiefly as a result of economic growth, energy use by North American transportation is expected to increase by 46% from 2003 to 2025 (U.S. DOE/EIA, 2005b). If the mix of fuels is assumed to remain the same, as it does in the IEO 2005 Reference Case projection, carbon dioxide emissions would increase from 2151 Mt CO_2 in 2003 to 3149 Mt CO_2 in 2025 (Fig. 7-7). Canada, the only one of the three countries to have committed to specific GHG reduction goals, is expected to show the lowest rate of growth in CO_2 emissions.

Figure 7-7. Projected carbon dioxide emissions from the North American transport sector in 2025.

The World Business Council for Sustainable Development (WBCSD), in collaboration with the International Energy Agency developed a model for projecting world transport energy use and greenhouse gas emissions to 2050 (Table 7-4). The WBCSD's reference case projection foresees the most rapid growth in carbon emissions from transportation occurring in Asia and Latin America (Fig. 7-8). Still, in 2050 North America accounts for 26.4% of global carbon dioxide emissions from transport vehicles (down from a 37.2% share in 2000).

Table 7-4. Global CO_2 emissions from transportation vehicles to 2050 by regions, WBCSD reference case projection.

Figure 7-8. WBCSD projections of world transportation vehicle CO_2 emissions to 2050.

OPTIONS FOR MANAGEMENT

Dozens of policies and measures for reducing petroleum consumption and mitigating carbon emissions from transportation in North America have been identified and assessed (e.g., U.S. DOT, 1998; IEA, 2001; Greene and Schafer, 2003; Greene *et al*., 2005; CBO, 2003; Harrington and McConnell, 2003; NRTEE, 2005). However, there is no consensus about how much transportation GHG emissions can be reduced and at what cost. In general, top-down models estimating the mitigation impacts of economy-wide carbon taxes or cap-and-trade systems find the cost of mitigation high and the potential modest. On the other hand, bottom-up studies evaluating a wide array of policy options tend to reach the opposite conclusion. Part of the explanation of this paradox may lie in the predominant roles that governments play in constructing, maintaining, and operating the majority of transportation infrastructure and in the strong interrelationship between land use planning and transportation demand. Estimates of the costs and benefits of mitigation policies also vary widely and depend critically on premises concerning (1) the efficiency of transportation energy markets, (2) the values consumers attach to vehicle attributes such as acceleration performance and vehicle weight, and (3) the current and future status of carbon-related technology.

A U.S. Energy Information Administration evaluation of a greenhouse gas cap and trade system, expected to result in carbon permit prices of \$79/t C in 2010 and \$221/t C in 2025, was estimated to reduce 2025 transportation energy use by 4.3 PJ and to cut transportation's carbon dioxide emissions by 10% from 826 Mt C in the reference case to 744 Mt C under this policy (U.S. DOE/EIA, 2003). The average fuel economy of new light-duty vehicles was estimated to increase from 26.4 mpg (8.9 L per 100 km) to 29.0 mpg (8.1 L per 100 km) in the policy case, an improvement of only 10%. A 2002 study by the U.S. National Academy of Sciences (NAS, 2002) estimated that "cost-efficient" fuel economy improvements for U.S. light-duty vehicles using proven technologies ranged from 12% for subcompact cars to 27% for large cars, and from 25% for small SUVs to 42% for large SUVs. The NAS study did not include the potential impacts of diesel or hybrid vehicle technologies and assumed that vehicle size and horsepower would remain constant.

The U.S. Congressional Budget Office (CBO, 2003) estimated that achieving a 10% reduction in U.S. gasoline use would create total economic costs of approximately \$3.6 billion per year if accomplished by means of Corporate Average Fuel Economy (CAFÉ) standards, \$3.0 billion if the same standards allowed trading of fuel economy credits among manufacturers, and \$2.9 billion if accomplished via a tax on gasoline. This partial equilibrium analysis assumed that it would take about 14 years for the policies to have their full impact. If one assumes that the United States would consume 22,600 PJ of gasoline in 2017, resulting in 1,419 Mt of CO_2 emissions, then a 10% reduction amounts to 142 Mt CO_2. At a total cost of \$3 billion per year, and attributing the full cost to carbon reduction (vs other objectives such as reducing petroleum dependence) produces an upper-bound mitigation cost estimate of \$21/t CO_2.

Systems of progressive vehicle taxes on purchases of less efficient new vehicles and subsidies for more efficient new vehicles ("feebates") are yet another alternative for increasing vehicle fuel economy. A study of the U.S. market (Greene *et al*., 2005) examined a variety of feebate structures under two alternative assumptions: (1) consumers consider only the first three years of fuel savings when making new vehicle purchase decisions, and (2) consumers consider the full discounted present value of lifetime fuel savings. The study found that if consumers consider only the first three years of fuel savings, then a feebate of \$1000 per 0.01 gal/mile (3.5 L per 100 km), designed to produce no net revenue to the government, would produce net benefits to society in terms of fuel savings and would reduce carbon emissions by 139 Mt C (510 Mt CO_2) in 2030. If consumers fully valued lifetime fuel savings, the same feebate system would cause a \$3 billion loss in consumers' surplus (a technical measure of the change in economic well-being closely approximating income loss) and reduce carbon emissions by only 67 Mt C (246 Mt CO_2), or an implied cost of \$12/Mt CO_2.

The most widely proposed options for reducing the carbon content of transportation fuels are liquid fuels derived from biomass and hydrogen produced from renewables, nuclear energy, or from fossil fuels with carbon sequestration. Biomass fuels, such as ethanol from sugar cane or cellulose or liquid hydrocarbon fuels produced via biomass gasification and synthesis, appear to be a promising near- and long-term option, while hydrogen could become an important energy carrier after 2025 (WBCSD, 2004). The carbon emission reduction potential of biomass fuels for transportation is strongly dependent on the feedstock and conversion processes. Advanced methods of producing of ethanol from grain, the predominant feedstock in the United States can reduce carbon emissions by up to 30% (Wang, 2005; p. 16 in IEA, 2004). Production of ethanol from sugar cane, as is the current practice in Brazil, or by not-yet-commercialized methods of cellulosic conversion can achieve up to a 90% net reduction over the fuel cycle. Conversion of biomass to liquid hydrocarbon fuels via gasification and synthesis may have a similar potential (Williams, 2005). The technical potential for liquid fuels production from biomass is very large and very uncertain; recent estimates of the global potential range from 10 to 400 exajoules per year (see Table 6.8 in IEA, 2004). The U.S. Departments of Energy and Agriculture have estimated that 30% of U.S. petroleum use could be replaced by biofuels by 2030 (Perlack *et al*., 2005). The economic potential will depend on competition for land with other uses, the development of a global market for biofuels, and advances in conversion technologies.

Hydrogen must be considered a long-term option because of the present high cost of fuel cells, technical challenges in hydrogen storage, and the need to construct a new infrastructure for hydrogen production and distribution (NAS, 2004; U.S. DOE, 2005). Hydrogen’s potential to mitigate carbon emissions from transport will depend most strongly on how hydrogen is produced. If produced from coal gasification without sequestration of CO_2 emissions in production, it is conceivable that carbon emissions could increase. If produced from fossil fuels with sequestration, or from renewable or nuclear energy, carbon emissions from road and rail vehicles could be virtually eliminated (General Motors *et al*., 2001).

In a comprehensive assessment of opportunities to reduce GHG emissions from the U.S. transportation sector, a study published by the Pew Center on Global Climate Change (Greene and Schafer, 2003) estimated that sector-wide reductions in the vicinity of 20% could be achieved by 2015 and 50% by 2030 (Table 7-4). The study’s premises assumed no change in the year 2000 distribution and efficiency of energy use by mode. A wide range of strategies was considered, including research and development, efficiency standards, use of biofuels and hydrogen, pricing policies to encourage efficiency and reduce travel demand, land-use transportation planning options, and public education (Table 7-5). Key premises of the analysis were that (1) for efficiency improvements the value of fuel saved to the consumer must be greater than or equal to the cost of the improvement, (2) there is no change in vehicle size or performance, (3) pricing policies shift the incidence but do not increase the overall cost of transportation, and (5) there is a carbon cap and trade system in effect equivalent to a charge of approximately $50/t C. Similar premises underlie the 2030 estimates, except that technological progress is assumed.

Table 7-5. Potential impacts of transportation GHG reduction policies in the United States by 2015 and 2030 based on the 2000 distribution of emissions by mode and fuel.

The Pew Center study notes that if transportation demand continues to grow as the IEO 2005 and WBCSD projections anticipate, the potential reductions shown in Table 7.4 would be just large enough to hold U.S. transportation CO_2 emissions in 2030 to 2000 levels.

A study for the U.S. Department of Energy (ILWG, 2000) produced estimates of carbon mitigation potential for the entire U.S. economy using a variety of policies generally consistent with carbon taxes of \$25–\$50/t C. In the study's business as usual case, transportation CO_2 emissions increased from 1752 Mt CO_2 in 1997 to 2567 Mt CO_2 in 2020. A combination of technological advances, greater use of biofuel, fuel economy standards, paying for a portion of automobile insurance as a surcharge on gasoline, and others, were estimated to reduce 2020 transportation CO_2 emissions by 569 Mt CO_2 to 1998 Mt CO_2. The study did not produce cost estimates and did not consider impacts on global energy markets.

A joint study of the U.S. Department of Energy and Natural Resources Canada (Patterson *et al.*, 2003) considered alternative scenarios of highway energy use in the two countries to 2050. The study did not produce estimates of cost-effectiveness for greenhouse gas reduction strategies but rather focused on the potential impacts of differing social, economic, and technological trends. Two of the scenarios describe paths that lead to essentially constant greenhouse gas emissions from highway vehicles through 2050 through greatly increased efficiency and biofuel and hydrogen use and, in one scenario, reduced demand for vehicle travel.

RESEARCH AND DEVELOPMENT NEEDS

Research needs with respect to the transport sector as a part of the carbon cycle fall into three categories: (1) improved data, (2) comprehensive assessments of mitigation potential, and (3) advances in key mitigation technologies and policies for transportation. The available data are adequate to describe carbon inputs by fuel type and carbon emissions by very broad modal breakdowns by country. The North American Transportation Statistics project made a start at producing comprehensive and consistent estimates for all three countries. However, there are many items of missing data, and the country-specific time series are incomplete. Knowledge of the magnitudes of GHG emissions by type of activity and fuel and of trends is essential if policies are to be focused on the most important GHG sources. A consistent description of the accuracy of each country's data is also needed.

The most pressing research need is for comprehensive, consistent, and rigorous assessments of carbon emissions mitigation potential for North America. The lack of such studies for North America parallels a similar dearth of global analyses noted by the Intergovernmental Panel on Climate Change (Moomaw and

Moreira, 2001). Existing studies focus almost exclusively on a single country, with premises and assumptions varying widely from country to country. Even the best single country studies omit the impacts of carbon reduction policies on global energy markets. Knowledge of how much contribution the transport sector can make to GHG mitigation at what cost and what options and measures are capable of achieving those potentials is crucial to the global GHG policy discussion.

Highly promising technologies for reducing transportation GHG emissions include hybrid vehicles, plug-in hybrid vehicles capable of accepting electrical energy from the grid, and fuel cell vehicles powered by hydrogen. While hybrids are already in the market and fuel cell vehicles are still years away, all three technologies would benefit from cost reduction. Hydrogen fuel cell vehicles also face significant technological challenges with respect to hydrogen storage and fuel cell durability. Technologies exist that could greatly reduce greenhouse gas emissions from other transport modes. For example, blended wing-body aircraft designs could reduce fuel burn rates by one-third. Biofuels in the near term and hydrogen in the longer term appear to be the most promising low-carbon fuel options. To achieve the greatest greenhouse gas reduction benefits, biofuels must be made from plants' lingo-cellulosic components either by conversion to alcohol or by gasification and synthesis of liquid hydrocarbon fuels. Cost reductions in both feedstock production and fuel conversion are needed.

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Table 7-1. Carbon dioxide emissions from transportation in North America in 2003

	Carbon dioxide emissions (Mt CO_2)
North America	2151
Canada	1865
United States	169
Mexico	117

Note: Summarized from Table 7-3 in this chapter.

Table 7-2. Summary of North American transport energy use and carbon dioxide emissions in 2003 by energy source or fuel type

North America energy source	Energy input (Petajoules)	Carbon input (Mt CO_2)
Gasoline	20,923	1,314
Diesel/distillate	7,344	475
Jet fuel/kerosene	2,298	251
Residual	681	53
Other fuels	124	5
Natural gas	926	36
Electricity	36	3
Unalloc./error	466	0
Total	32,798	2,137
United States		
Gasoline	18,520	1,146
Diesel/distillate	6,193	393
Jet fuel/kerosene	1,986	229
Residual	612	48
Other fuels	50	1
Natural gas	748	35
Electricity	20	3
Unalloc./error	466.2	
Total	28,595.2	1,855
Sources: U.S. EPA, 2005, Tables 3-7 and 2-17; Davis and Diegel, 2004, Tables 2.6 and 2.7.		
Canada		
Gasoline	1,337	96
Diesel/distillate	704	51
Jet fuel/kerosene	206	16
Residual	66	5
Other fuels	17	1
Natural gas	178	0
Electricity	12	0
Unalloc./error	0	
Total	2,518	169
NRCan, 2005, Tables 1 and 8.		
Mexico		
Gasoline	1,066	72
Diesel/distillate	447	31
Jet fuel/kerosene	106	7
Residual	4	0
Other fuels	57	3
Natural gas	1	0
Electricity	4	
Unalloc./error		
Total	1,685	114

Sources: Transportation energy use by fuel and mode from Rodriguez, 2005.

Source: Fulton and Eads, 2004, spreadsheet model, output worksheet.

Data sources differ somewhat by country with respect to modal, fuel, and greenhouse gas definitions so that the numbers are not precisely comparable. Canadian carbon emissions data include all greenhouse gases produced by transportation in CO_2 equivalents, while the U.S. data are CO_2 emissions only. Carbon dioxide emissions for Mexico were estimated by applying U.S. EPA emissions factors to the Mexican energy use data. Electricity is assumed to produce no carbon emissions in end use.

Table 7-3. Summary of North American transport energy use and carbon dioxide emissions in 2003 by mode of transportation

North America transport mode	Energy use (Petajoules)	Carbon emissions (Mt CO_2)
Road	25,830	1,698
Air	2,667	194
Rail	751	50
Waterborne	1,386	68
Pipeline	990	57
	0	84
Total	31,624	2,151
United States		
Road		
Light vehicles	17,083	1,113
Heavy vehicles	5,505	350
Air	2,335	171
Rail	655	43
Waterborne	1,250	58
Pipeline/other	986	47
Internatl./Bunker		84
Total	27,814	1,865
Source: U.S. EPA, 2005, Tables 3-7 and 2-17; Davis and Diegel, 2004, Tables 2-6 and 2-7.		
Canada		
Road		
Light vehicles	1,233	87
Heavy vehicles	491	46
Air	226	16
Rail	74	6
Waterborne	103	8
Pipeline/other		7
Total	2,126	169
Source: NRCan, 2005; Tables 1 and 8.		
Mexico		
Road	1,518	102
Light vehicles		
Heavy vehicles		
Air	107	7
Rail	22	2
Waterborne	33	2
Electric	4	4
Total	1,684	117
Source: Rodriguez, 2005.		

Data sources differ somewhat by country with respect to modal, fuel, and greenhouse gas definitions so that the numbers are not precisely comparable. Canadian carbon emissions data include all greenhouse gases produced by transportation in CO_2 equivalents, while the U.S. data are CO_2 emissions only. Carbon dioxide emissions for Mexico were estimated by applying U.S. EPA emissions factors to the Mexican energy use data. Electricity is assumed to produce no carbon emissions in end use.

Table 7-4. Global CO_2 emissions from transportation vehicles to 2050 by regions, WBCSD reference case projection

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	1995.6	2119.7	2285.0	2447.4	2594.4	2706.1	2814.8	2917.9	3021.1	3125.6	3232.5
OECD Europe	1146.3	1224.1	1314.7	1395.7	1438.1	1474.6	1510.7	1525.5	1540.2	1554.9	1569.7
OECD Pacific	489.2	499.5	521.9	542.2	560.5	574.4	589.0	603.7	620.1	637.7	656.4
FSU	176.9	203.7	234.1	274.3	324.2	361.1	401.2	444.0	484.4	523.2	561.5
Eastern Europe	84.1	92.7	103.3	115.6	130.2	142.0	154.6	172.2	191.9	214.4	240.4
China	251.9	314.8	394.9	488.8	599.0	702.7	826.8	967.8	1130.0	1316.2	1530.0
Other Asia	360.6	412.5	480.0	554.6	639.4	715.8	806.1	913.1	1037.7	1182.5	1350.1
India	137.6	163.9	199.6	242.1	292.0	338.8	395.2	457.8	534.2	628.1	743.5
Middle East	215.3	236.7	261.5	288.6	323.5	355.2	387.0	417.3	447.1	476.5	505.6
Latin America	348.2	397.8	467.0	543.1	630.5	703.1	792.0	892.2	1008.6	1141.2	1290.2
Africa	159.4	181.0	211.7	248.8	293.7	337.2	378.1	419.0	464.3	516.8	579.5
Total—All regions	**5364.9**	**5846.3**	**6473.6**	**7141.4**	**7825.4**	**8411.1**	**9055.5**	**9730.3**	**10479.7**	**11317.1**	**12259.4**

Source: Fulton and Eads, 2004.

Table 7-5. Potential impacts of transportation GHG reduction policies in the United States by 2015 and 2030[a] based on the 2000 distribution of emissions by mode and fuel (Greene and Schafer, 2003)

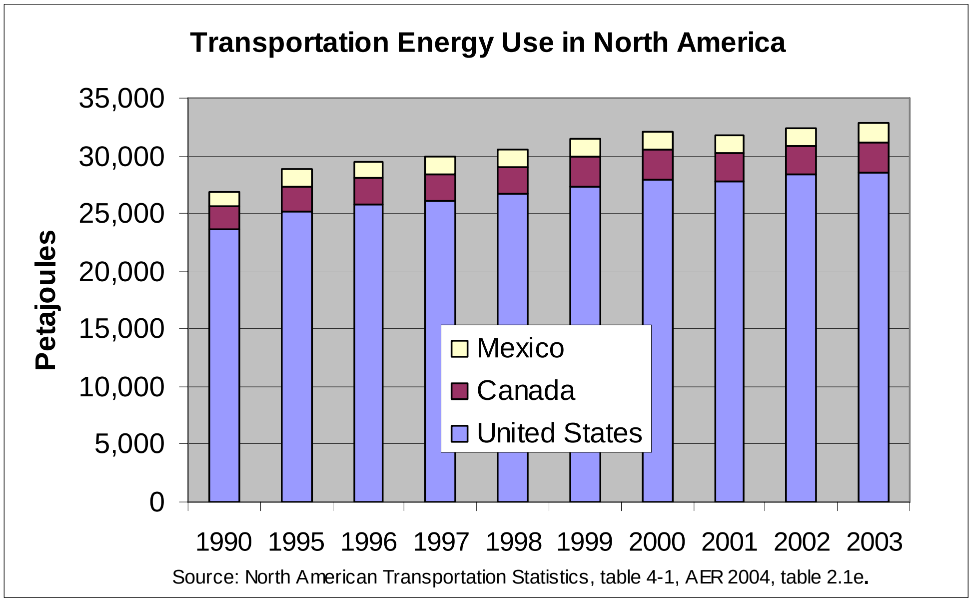
		Reduction potential per mode/fuel (%)		Transportation sector reduction potential (%)	
Management option	Carbon emission (Mt CO_2) 2000	2015	2030	2015	2030
Research, development and demonstration					
Light-duty vehicles (LDVs)	1061	11[b]	38[b]	7[b]	23[b]
Heavy trucks	294	11[b]	24[b]	2[b]	4[b]
Commercial aircraft	196	11[b]	27[b]	1[b]	3[b]
Efficiency standards					
Light-duty vehicles	1061	9	31	6	18
Heavy trucks	294	9	20	2	3
Commercial aircraft	196	9	22	1	2
Replacement and alternative fuels					
Low-carbon replacement fuels (~10% of LDV fuel)	100	30	100	2	7
Hydrogen fuel (All LDV fuel)	1061	1	6	1	4
Pricing policies					
Low-carbon replacement fuels (~10% of LDV fuel)	100	30	100	2	6
Carbon pricing (All transportation fuel)	1792	3	6	3	6
Variabilization (All highway vehicle fuel)	1355	8	12	6	9
Behavioral					
Land use and infrastructure (2/3 of highway fuel)	903	5	10	3	5
System efficiency (25% LDV fuel)	265	2	5	0	1
Climate change education (All transportation fuel)	1792	1	2	1	2
Fuel economy information (All LDV fuel)	1061	1	2	1	1
Total	**1792**			**22**	**48**

Notes:

[a] Carbon emissions for the year 2000 are used to weight percent reductions for the respective emissions source and example policy category in calculating total percent reduction potential. The elasticity of vehicle travel with respect to fuel price is –0.15 for all modes. Price elasticity of energy efficiency with respect to fuel price is –0.4.

[b] R&D efficiency improvements have no direct effect on total. Their influence is seen through efficiency standards impacts.

Policies affecting the same target emissions, such as passenger car efficiency, low carbon fuels, and land use policies are multiplicative, to avoid double counting [e.g. (1–0.1)*(1.0–0.2) = 1–0.28, a 28% rather than a 30% reduction.]



Source: North American Transportation Statistics, table 4-1, AER 2004, table 2.1e.

Fig. 7-1. Transportation energy use in North America, 1990–2003.

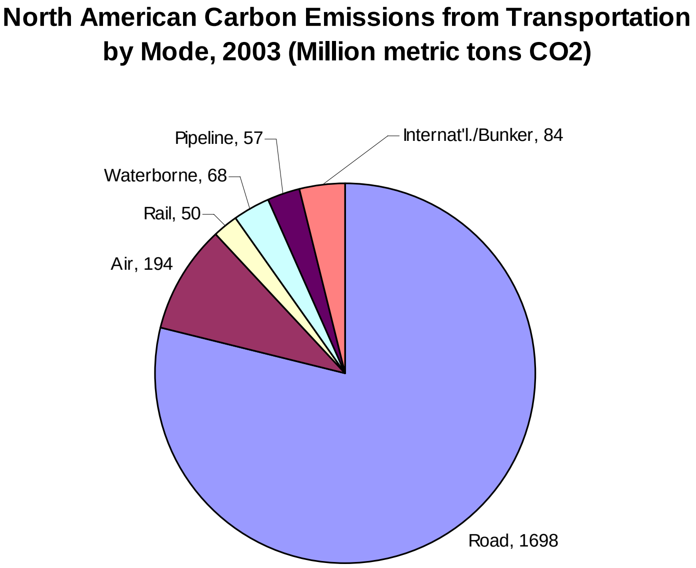


Fig. 7-2. North American carbon emissions from transportation by mode (million metric tons CO_2) 2003. *Source*: Table 7-3, this chapter.

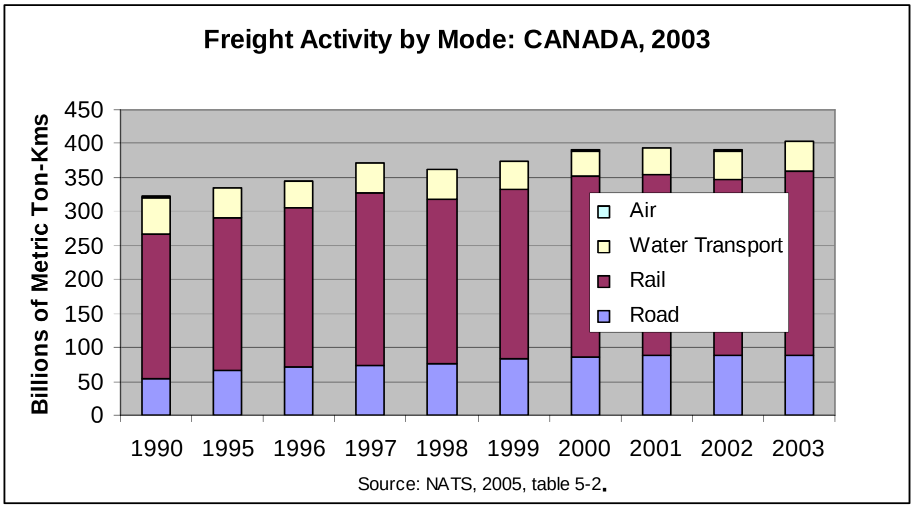


Fig. 7-3a. Freight activity by mode in Canada, Mexico, and the United States.

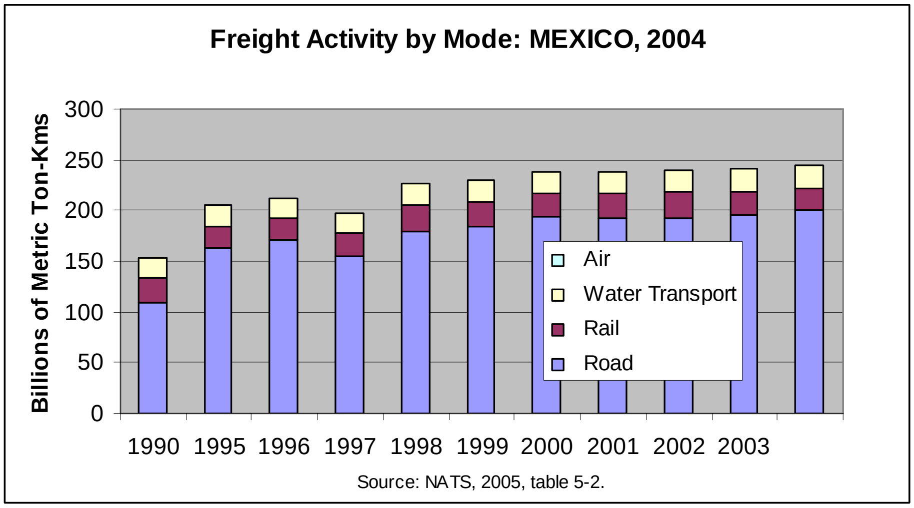


Fig. 7-3b. Freight activity by mode in Canada, Mexico, and the United States.

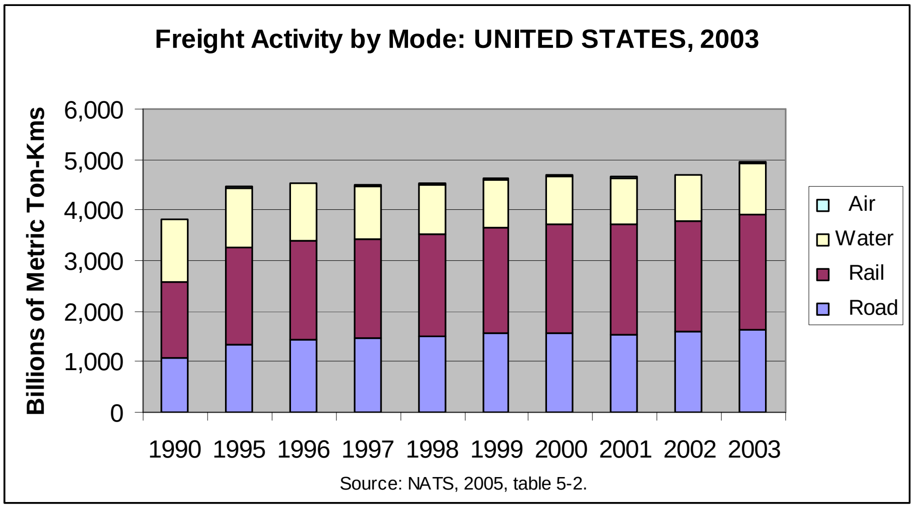


Fig. 7-3c. Freight activity by mode in Canada, Mexico and the United States.

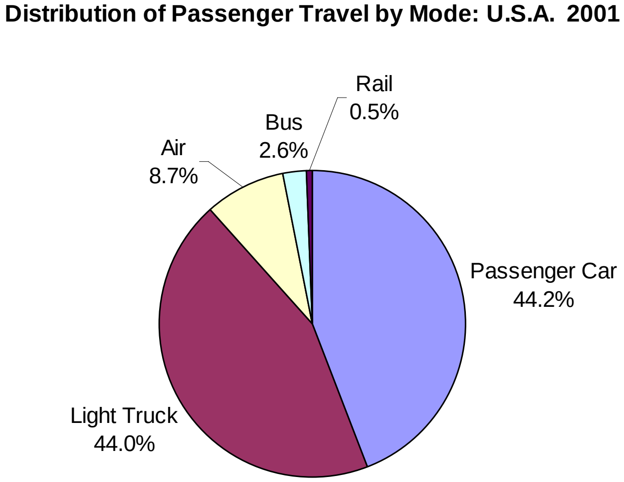


Fig. 7-4a. Distribution of passenger travel in the United States by mode. *Source*: Table 8-1 in NATS, 2005.

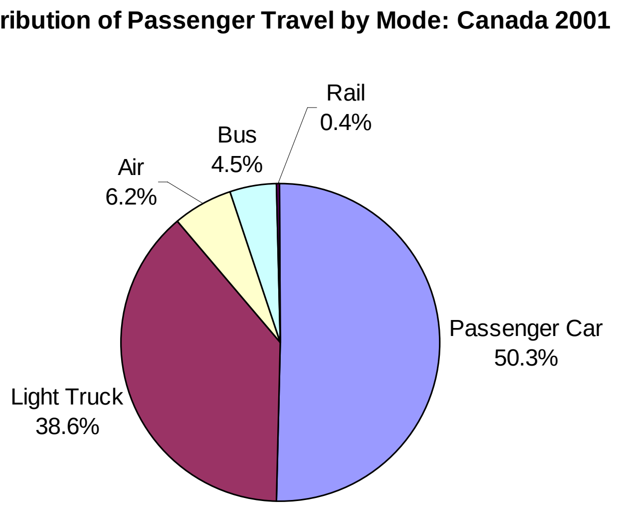
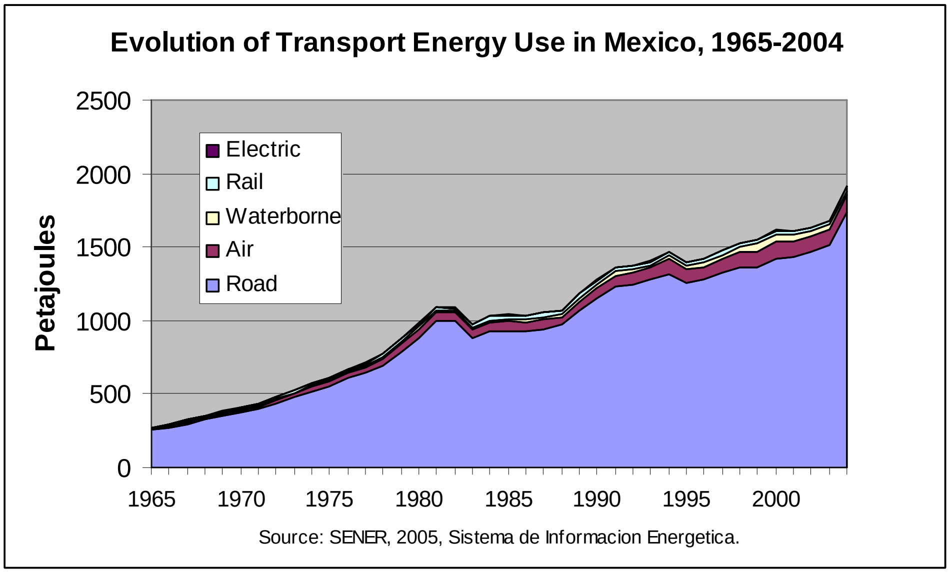
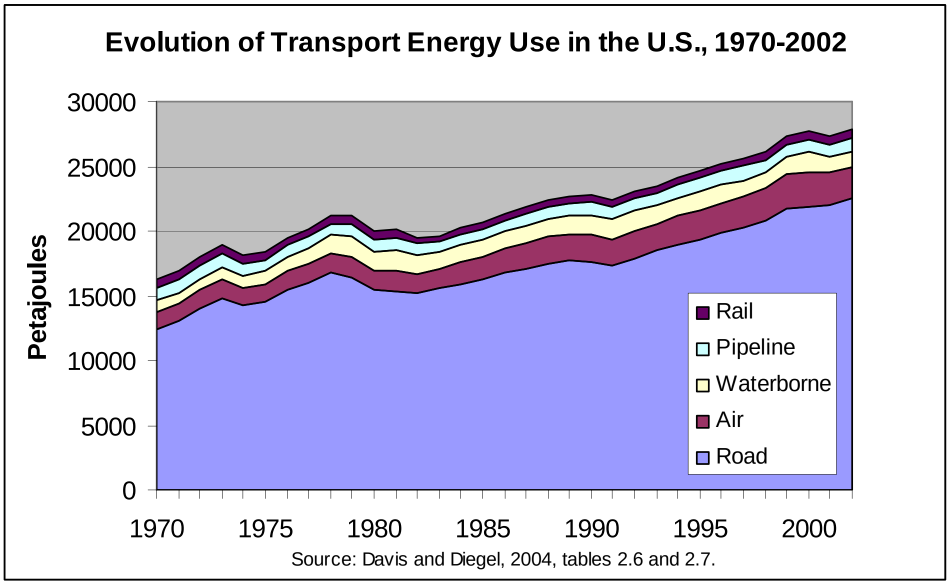


Fig. 7-4b. Distribution of passenger travel by mode in Canada. *Source*: Table 8-1 in NATS, 2005.



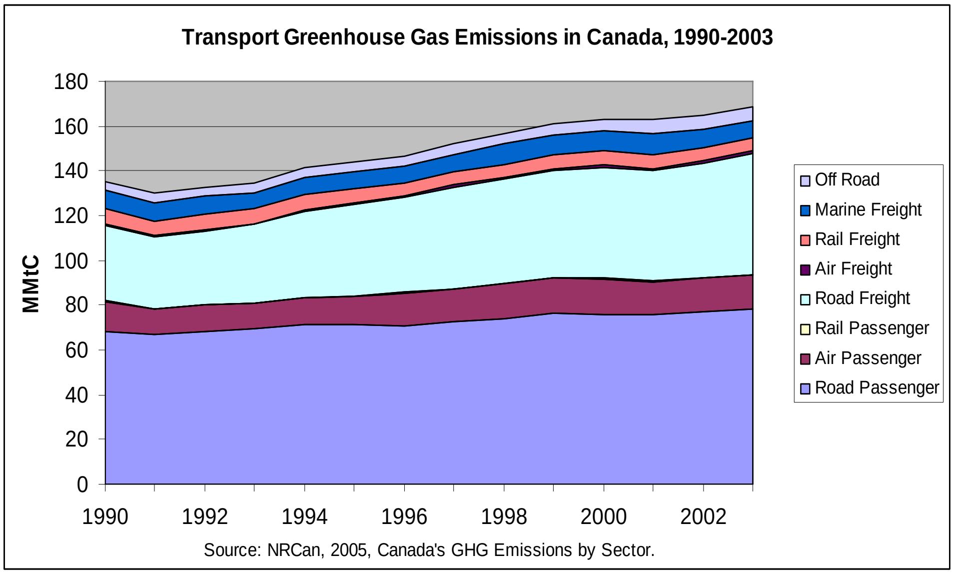
Source: SENER, 2005, Sistema de Informacion Energetica.

Fig. 7-5a. Evolution of transport energy use in Mexico and the United States.



Source: Davis and Diegel, 2004, tables 2.6 and 2.7.

Fig. 7-5b. Evolution of transport energy use in Mexico and the United States.



Source: NRCan, 2005, Canada's GHG Emissions by Sector.

Fig. 7-6a. Transport CO_2 emissions in Canada and the United States, 1990–2003.

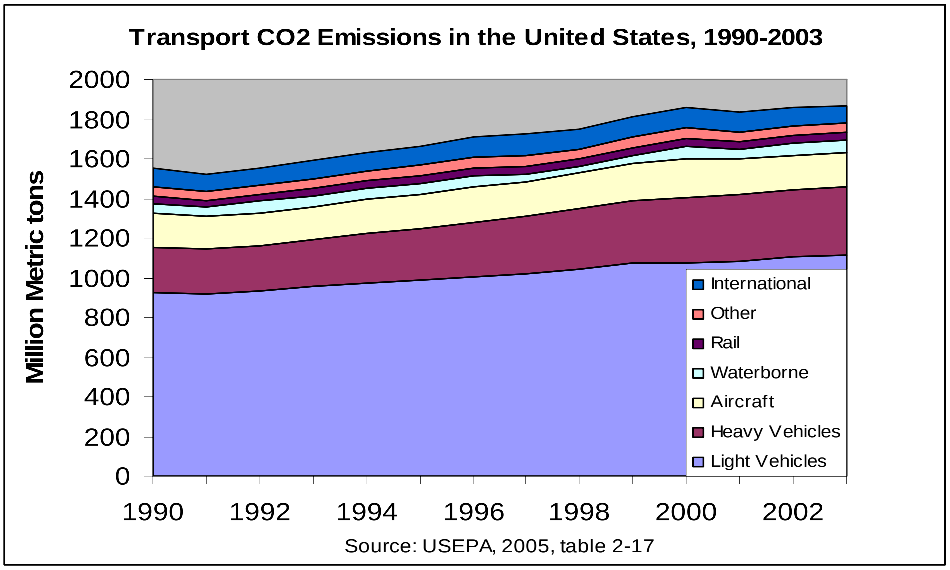


Fig. 7-6b. Transport CO_2 emissions in Canada and the United States, 1990–2003.

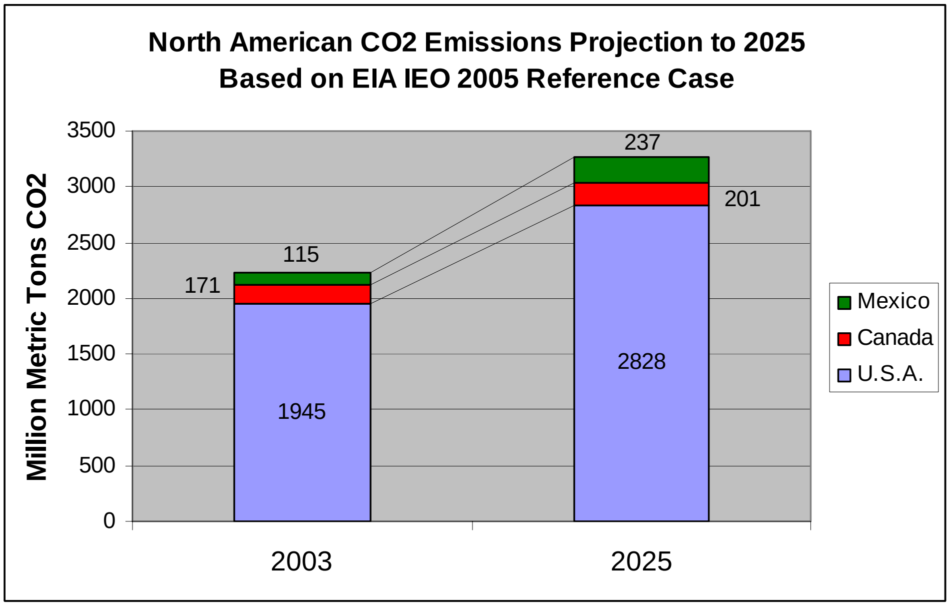


Fig. 7-7. Projected carbon dioxide emissions from the North American transport sector in 2025. *Source*: Fulton and Eads, 2004.

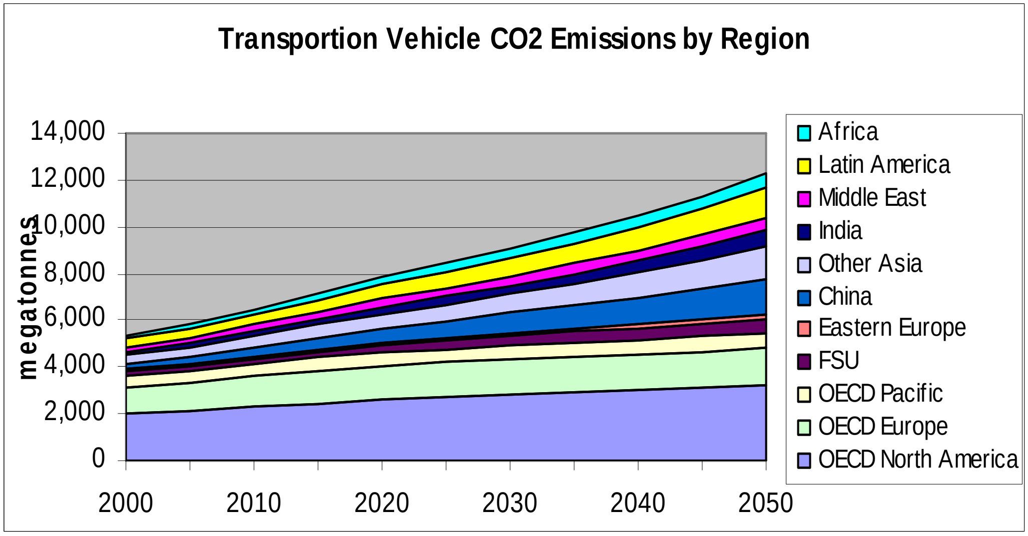


Fig. 7-8. WBCSD projections of world transportation vehicle CO_2 emissions to 2050.
Source: Fulton and Eads, 2004.