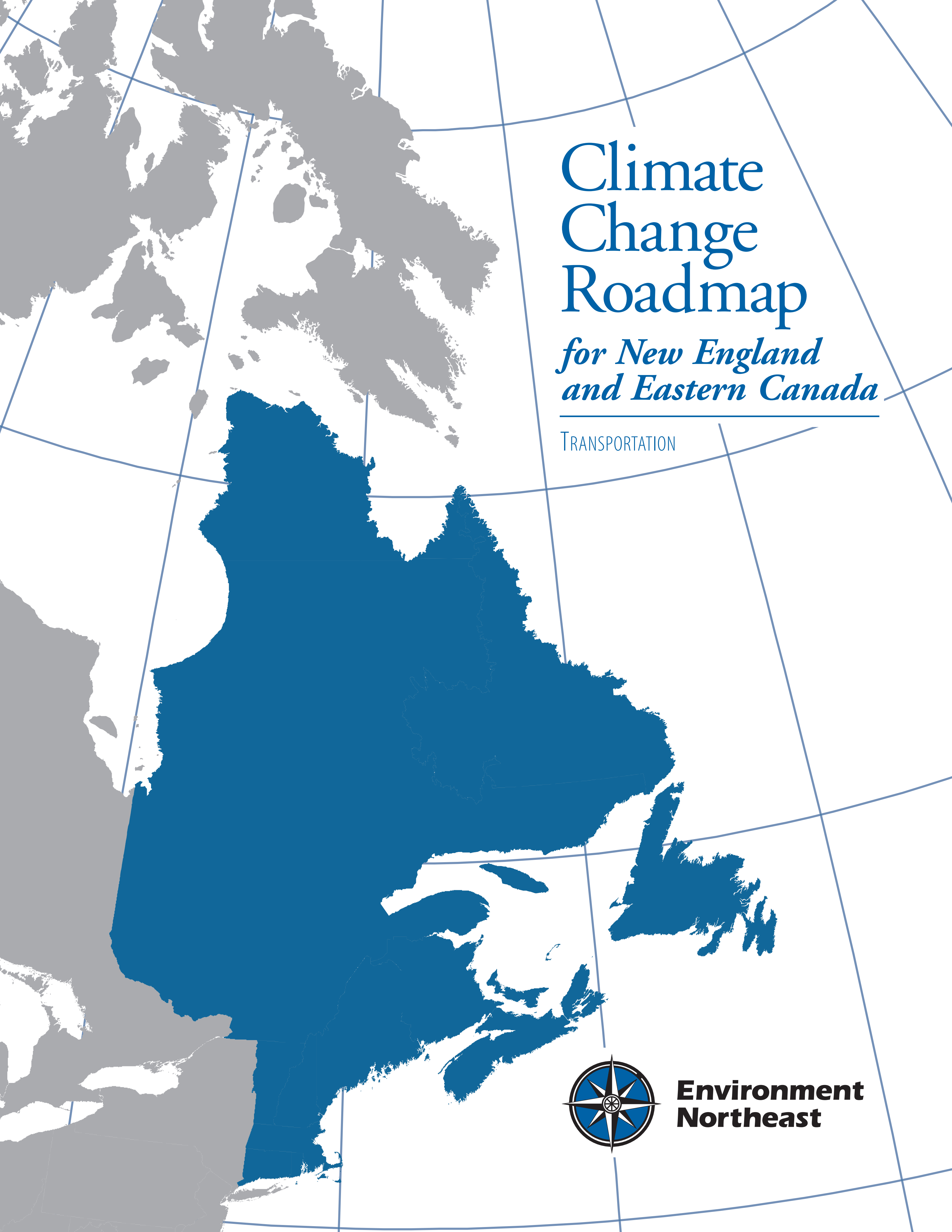


Climate Change Roadmap

for New England and Eastern Canada

TRANSPORTATION

Environment Northeast

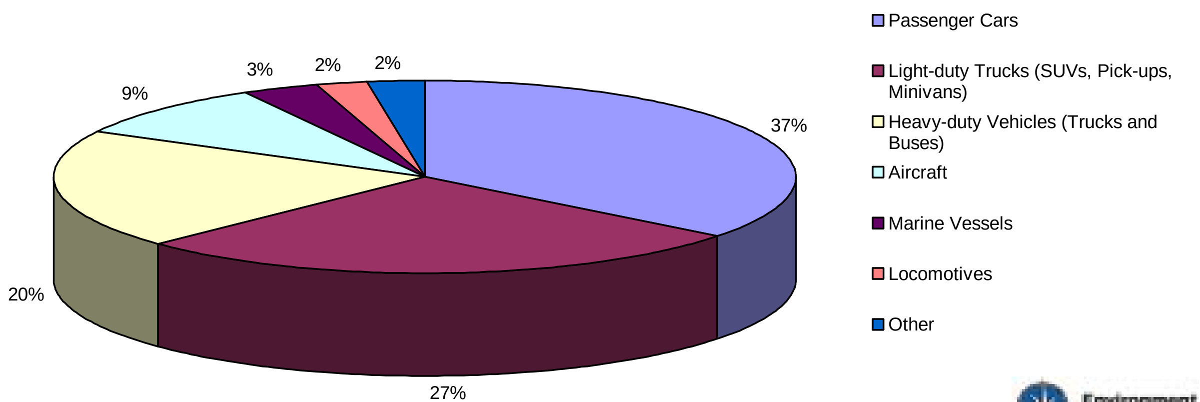
Chapter 2: Transportation

Introduction

Transportation and Greenhouse Gases

The transportation sector is composed of two broad categories of fleets: light-duty vehicles, which include passenger cars and light trucks (SUVs, pick-up trucks and minivans) and the heavy-duty fleet, which includes trucks, buses, marine vessels, locomotives and aircraft. See Figure 2.1 for a breakdown of transportation related GHG emissions in the U.S.

Figure 2.1: 2003 U.S. Transportation-Related Greenhouse Gas Emissions[1]



Environment Northeast

The transportation sector contributes 124 million of the 346 $MMTCO_2e$ generated annually in the NE-EC region, or approximately 35% of total GHG emissions.[2] Of the 124 $MMTCO_2e$ emitted in the region approximately two-thirds,[3] or 83 million metric tons, were emitted by light-duty vehicles and approximately one-third, or 41 million metric tons, were emitted by the heavy-duty transportation fleet. The majority of light-duty vehicles are powered by gasoline, while the heavy-duty fleet relies on mostly on diesel or jet-fuel. Figure 2.2 shows a breakdown of transportation fuel consumption for each state/province.

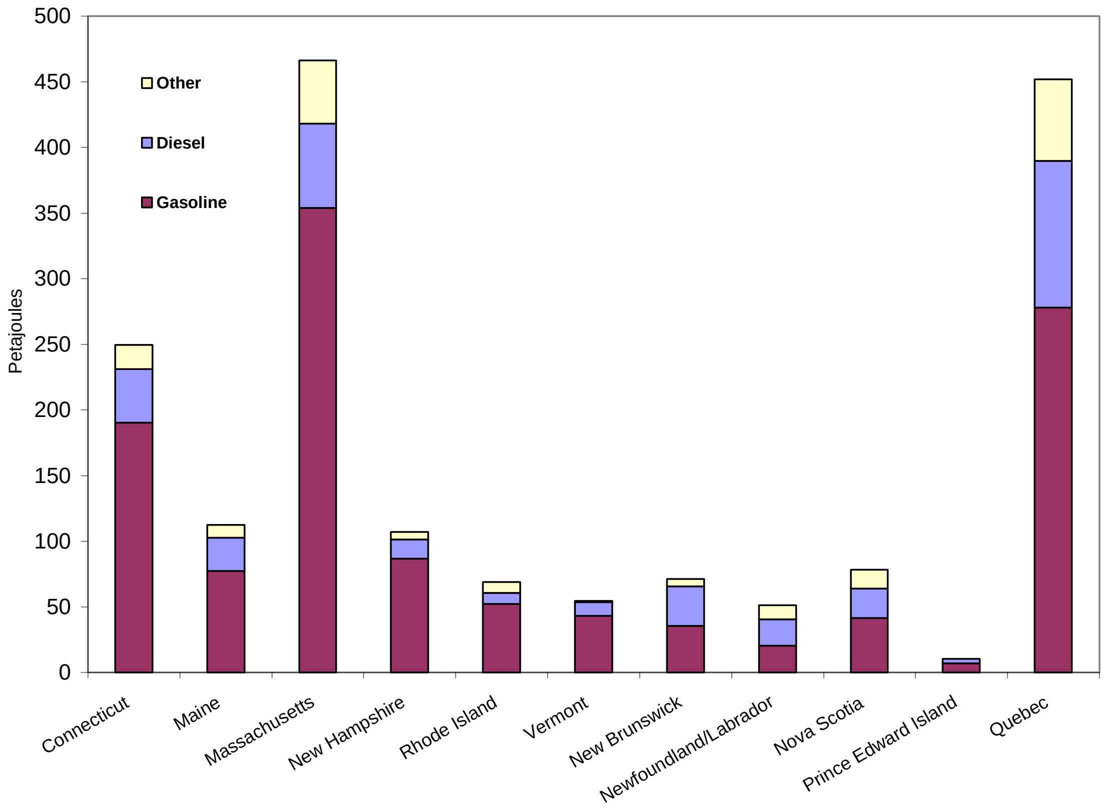
---

[1] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003 (April 2005) EPA 430-R-05-003 Table 2-17: Transportation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.). http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

[2] Data from NESCAUM & EPA Greenhouse Gas Inventory Tool for States (New England), and Natural Resources Canada (Eastern Canadian provinces).

[3] Light-duty vehicles in the U.S. produced 1152.6 Tg CO_2 Eq. in 2003, representing 77% of on-road vehicle GHG emissions and 62% of total transportation emissions. Data from http://www.epa.gov/otaq/climate/420r06003.pdf Specific percentages are not available for the NE states. Percent on-road transportation and percent total transportation for Canadian Provinces include NB: 66%, 50%; NF: 70%, 40%; NS: 71%, 50%; PEI: 76%, 59% QB: 69%, 58%.

Figure 2.2: 2001 Transportation Sector Energy Consumption by Fuel and State/Province[4]



As the prices of gasoline and diesel rise, these fuel consumption levels are of increasing consequence for the regional economy. Figures 2.3 and 2.4 illustrate the upward trend in gasoline prices and the total amount spent on the commodity in the region.

---

[4] ENE calculations using Canadian Information from Canada Center for Energy, at http://www.centreforenergy.com/outsideNav.asp?href=http%3A%2F%2Foee%2Enrcan%2Egc%2Eca%2Fcorporate%2Fstatistics%2Fneud%2Fdpa%2Fcomprehensive%5Ftables%2Findex%2Ecfm%3Fattr%3D0&template=1,19 and EIA Projections to 2030 for New England, at http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_tra.html.

Figure 2.3: Commodity and Retail Cost of Gasoline in New England

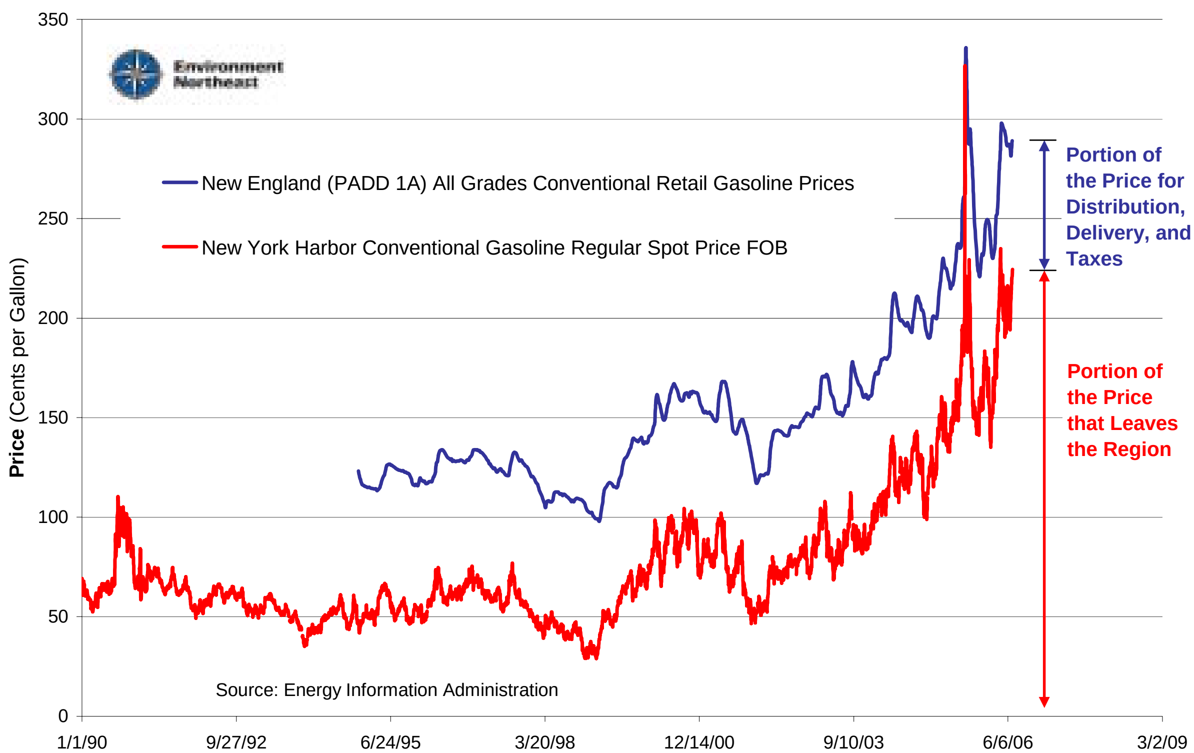
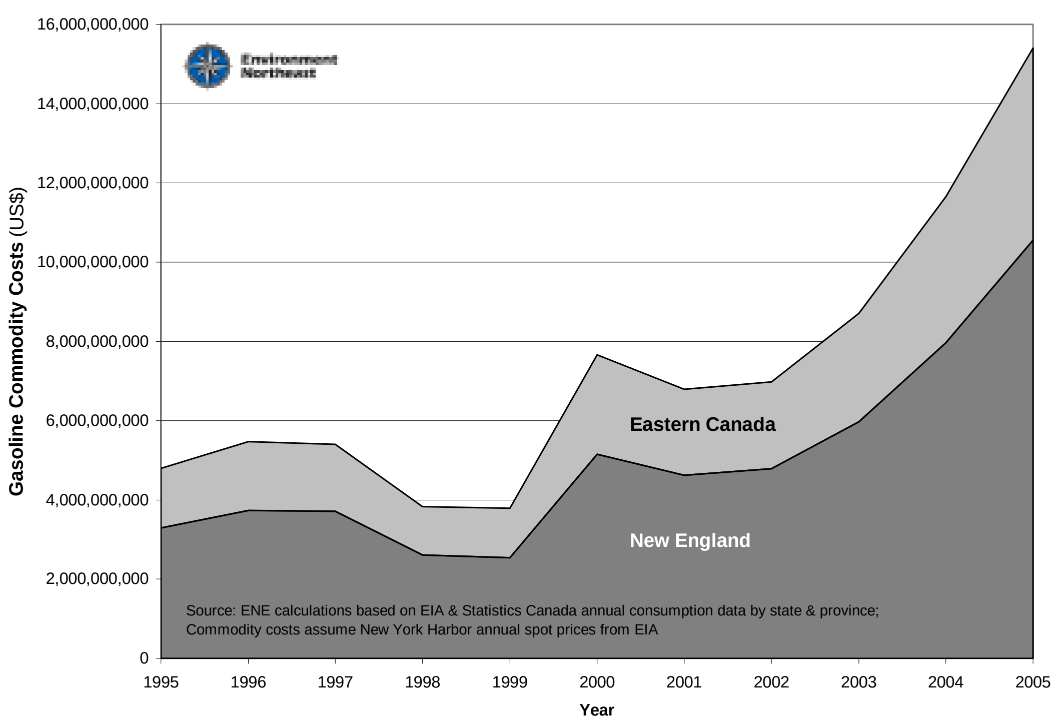


Figure 2.4: Total Expenditures in New England and Eastern Canada on Gasoline Commodity
Based on actual consumption in each state and province and New York Harbor commodity prices



As demonstrated in Figures 2.5 and 2.6, similar increases in cost and total expense apply to the diesel fuel that powers the heavy-duty vehicle fleet.

Figure 2.5: Commodity and Retail Cost of Diesel in New England

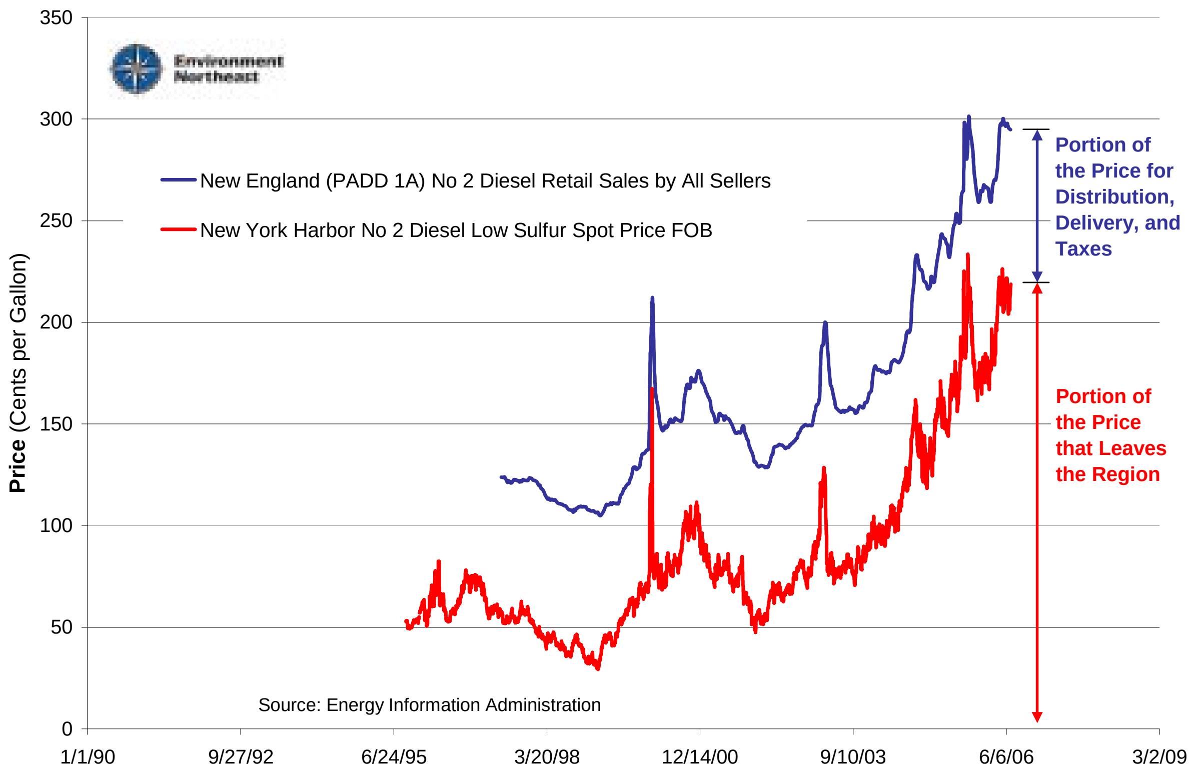
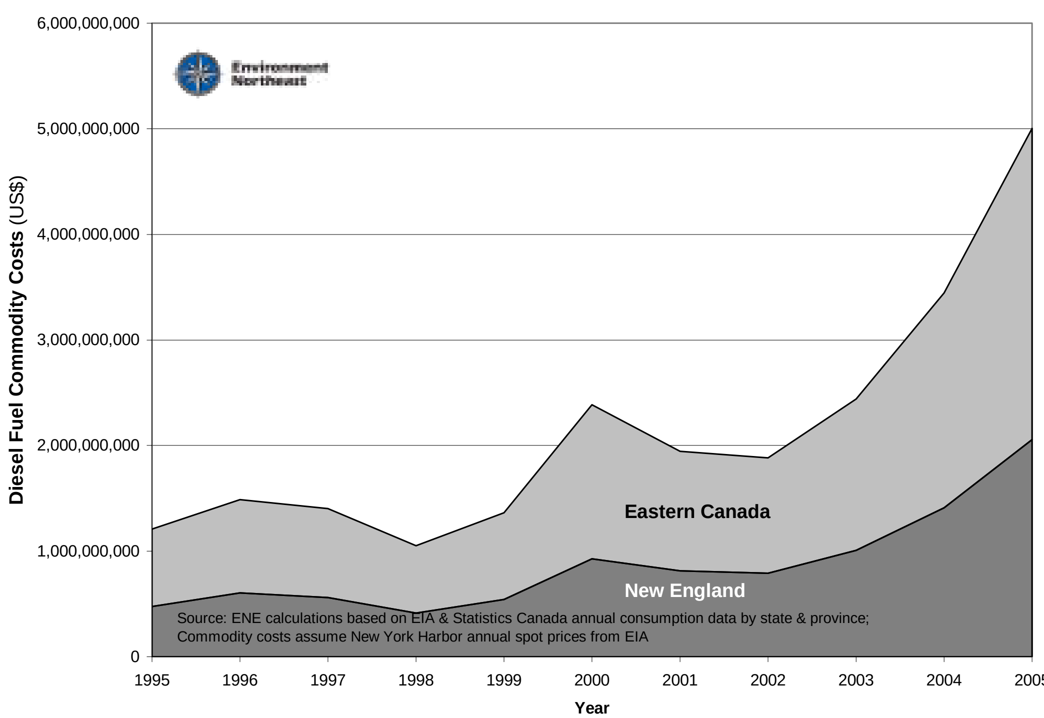


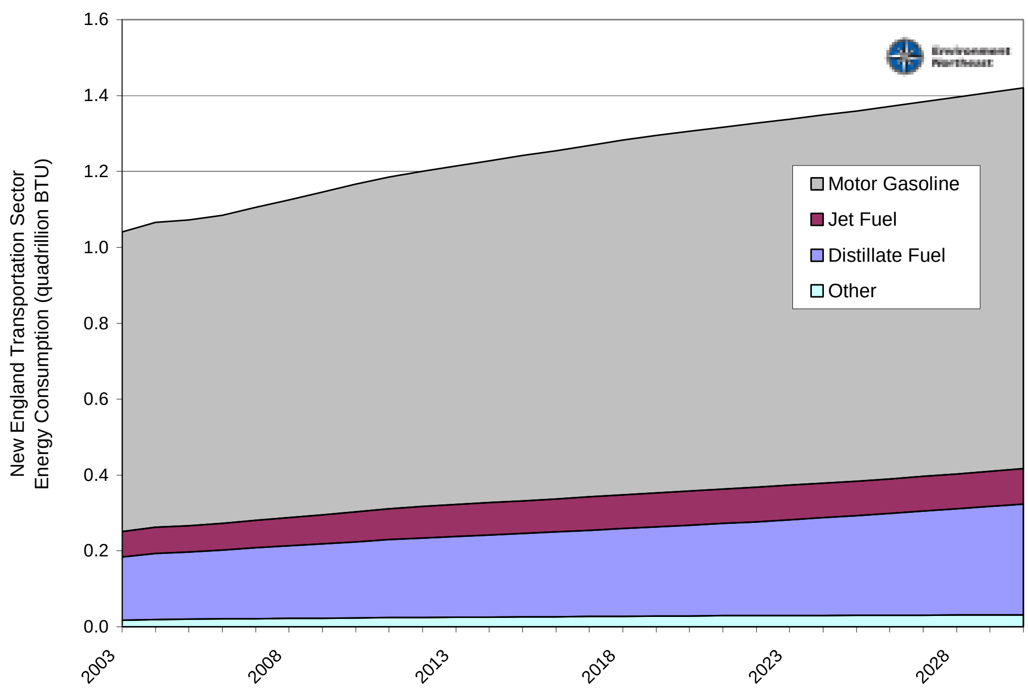
Figure 2.6: Total Expenditures in New England and Eastern Canada on Diesel Commodity
Based on actual consumption in each state and province and New York Harbor commodity prices



These fuel expenditures represent a significant drain on the NE-EC economy. In 2005, $20 billion left the region with the purchase of transportation fuels. Measures that reduce the amount of gasoline and diesel consumed, such as increasing efficiency, reducing the amount of miles traveled, and switching to alternative fuels, will mitigate this economic loss and allow more dollars to stay in the NE-EC region.

The path to making such reductions may not be easy or straightforward. The NEG-ECP recognized the very significant hurdles to achieving significant reductions from transportation sources in the 2001 Climate Change Action Plan.[5] As the largest and fastest growing source of GHG and primary energy consumption in New England and Eastern Canada, the transportation sector presents a particular challenge to meeting the 75-85% long term emission reduction goals. It is in the context of these expectations for high activity and emissions growth that potential climate-stabilizing policy scenarios must be considered.

Figure 2.7: New England Transportation Sector Energy Consumption Energy Information Administration Projections to 2030[6]



We have divided transportation issues into three categories: fuels (or energy carriers), light-duty vehicles, and heavy-duty vehicles. The paths to reducing GHGs from mobile sources are the same as in the energy sector, and in simple terms they involve:

- making fuels and engines cleaner;
- making engines and transportation systems more efficient.

[5] "Slowing the growth of emissions in the transportation sector presents one of the most significant challenges to overall climate change mitigation efforts," NEG-ECP 2001 Climate Action Plan (17), http://69.13.128.176/newsletters/News_NEG-ECP_Climate_Change_Action_Plan_(July_2001).pdf

[6] ENE Calculations using New England EIA Projections to 2030. http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_tra.html

Applying these goals to our three mobile source categories, we have identified the following recommendations that are discussed below:

- establish a declining net GHG fuel standard;
- explore pathways to develop low-GHG biofuels in the region;
- explore the expansion of electric mobility infrastructure;
- implement emission standards for all light-duty vehicles;
- improve fuel economy standards in the U.S. and Canada;
- reduce vehicle miles traveled (VMT);
- reduce black carbon emissions from in-use diesel engines;
- promote improved efficiency of heavy-duty vehicles;
- improve the efficiency of the region’s freight transportation system.

Priority 6: Transition to No-Carbon or Low-Carbon Transportation Fuels

By: Michael Stoddard and Derek Murrow

Today, nearly 100% of the North American transportation system is fueled by gasoline and diesel fuel made from petroleum. A very modest number of trains, subways, trolleys and cars are run on electricity, and a growing but still tiny fraction of cars, trucks and non-road vehicles use "alternative fuels" like ethanol or compressed natural gas (CNG).

The infrastructure for running this transportation system consists of the following major components:

- refineries, which refine petroleum (oil) into gasoline or diesel motor fuel;
- pipelines, tanker ships and tanker trucks to move the refined products to filling stations;
- filling stations and storage tanks;
- an interconnected system of highways, secondary roads, city streets, bridges and tunnels;
- an interconnected system of railways for passengers and freight;
- waterways and ports for marine vessels;
- airports.

By 2050, the transportation system our children and grandchildren ride around on should not look the same as the one we use today.

First, the more urbanized areas of North America have begun to experience traffic congestion that is unsustainable. Greater Boston, Southern Connecticut and Montreal have significant congestion problems. Projections are that traffic and vehicle miles traveled will continue to increase and that, in places like Connecticut, conventional solutions such as adding more public transit or widening highways have reached the limit of their effectiveness.

Second, cheap petroleum from which to make gasoline and diesel may be a thing of the past. Many factors are at work, among them potentially declining reserves of oil, surging demand from emerging large economies in China and India and political instability in key oil-exporting nations.[7] The price of a barrel of oil has risen from below $30 per barrel (bbl) a decade ago to above $70 per bbl at the time of this writing, and U.S. DOE projects that prices will remain at or above current levels for the next several years.

Third, reliance on a petroleum-fueled transportation system is incompatible with climate stabilization. Climate stabilization and a sustainable mobility system will require that by mid-century we satisfy our transportation needs with an energy supply that emits at least 75-85% less GHG than currently emitted from this sector. This target will likely need to be even lower by the end of the century. This long-range target cannot realistically be achieved through any scenario in which there is continued widespread use of engines using conventional fuels (*e.g.*, petroleum-based gasoline or diesel) as a principal source of energy.

For example, we do not think that it is a realistic possibility that this target could be met by convincing North Americans to drive 75-85% fewer miles (or kilometers) by mid-century than they do today. Nor do we think it is realistic that manufacturers can make all gasoline-powered internal combustion engines use less than one-quarter the fuel they use today. While reducing vehicle miles traveled (VMT) and

[7] *See, e.g.*, Deffeyes, K., *Hubbert's Peak : The Impending World Oil Shortage*, 2005; Simmons, M., *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy*, 2005.

improving vehicle fuel economy will both be very important to attaining the mid-century target, they will not by themselves get the job done.

What should get the job done is complementing these tools with changes in transportation fuels and systems. By the end of this century, for both climate reasons and economic sustainability reasons, our transportation system should:

- have a significant portion of vehicles running on no-carbon or low-carbon energy carriers (*i.e.*, fuels or electricity that emit little or no carbon or other GHGs when viewed from a full-lifecycle perspective);
- have in place the systems, such as fuel storage and delivery infrastructure, as well as road, rail and port infrastructure, necessary to accommodate the vehicles using these energy carriers.

For use in transportation, there are several candidates of no-carbon and low-carbon energy carriers that may contribute to a sustainable transportation system. (*See also*, our discussion and figures related to energy sources and energy carriers under Priority 1.5 in the Energy Chapter.) Of primary interest to us in the NE-EC region are biofuels, electricity and hydrogen.

Biofuels

A variety of liquid and gaseous transportation fuels can be made from various types of biomass. Among these fuels are ethanol, synthetic gasoline or synthetic diesel fuel, hydrogen and synthetic natural gas.[8] To assess the net climate impact of a biofuel, it is necessary to factor into the equation the GHG emissions from a wide range of activities, including cultivating the land on which the fuel was grown, producing farm inputs like fertilizer, farm operations, processing the fuel, and transportation it to its final destination.[9] To date, we view the analyses of the net climate impacts of biofuel production to be preliminary and in need of additional research, so any current estimates of net GHG impacts should be viewed as preliminary or illustrative. In particular, the boundary conditions of the different analysis are often different and the impact of land conversion is often not factored in.

Electricity

Electricity emits no carbon when used on board the vehicle. As discussed in detail in the Energy chapter, electricity technically can be made with no-carbon or low-carbon emissions from energy resources such as renewable energy, fossil fuels (if the carbon is captured and sequestered), or other non-emitting sources. The actual net GHG impact of using electricity to run vehicles depends on what source of energy is used to make the electricity and how it is delivered to the vehicle. Electricity that is produced from no-carbon sources could be an important energy carrier in a sustainable mobility system.

Hydrogen

Like electricity, hydrogen is an energy carrier that emits no carbon from use on board a vehicle. Also as with electricity and biofuels, the net GHG emissions of hydrogen fuel depend almost entirely on how it is produced. Electrolysis of water using electricity from non-emitting sources, while expensive, produces essentially zero carbon emissions. Extracting hydrogen from gasified fossil fuels and/or biofuels, in conjunction with carbon capture and sequestration, also produces low carbon emissions. In this category, we include hydrogen rich fuels, *i.e.*, fuels with a high hydrogen content blended together with other fuels. The net GHG impact of such hydrogen rich fuels depends largely on what feedstock and

---

[8] Regarding production of synthetic gases from biomass, see, www.ieiglobal.org/ESDVol1No5/biomasstransport.pdf.
[9] *See generally*, Mark Delucchi, "Lifecycle Analysis of Biofuels – Draft Manuscript," May 2006, pp. 45 – 69, http://www.its.ucdavis.edu/publications/2006/LCAs_of_Biofuels.pdf .

process are used to produce the hydrogen and blended fuels, and the degree to which carbon by-products of production are captured and sequestered.

Five years ago, in our first publication on climate action options for North America, we highlighted the huge potential for hydrogen to lower the transportation sector's carbon emissions. We envisioned then that light vehicles would burn hydrogen in internal combustion engines or use it in fuel cells to power the vehicle with on-board electricity. We assumed that progress in the engineering of fuel cells and their subsequent mass production would resolve existing technical and cost barriers. The main challenge, we thought, would be to build out the infrastructure to produce, store and distribute the hydrogen itself. This scenario is still possible, but we think it less likely and farther down the road than others.

First, the chicken-and-egg situation facing fuel cells and hydrogen infrastructure has impeded progress. Economies of scale for fuel cells depend on the development of an infrastructure to produce and distribute hydrogen supplies. The huge expense of building a hydrogen infrastructure will not be undertaken until it becomes clearer that hydrogen fueled vehicles are likely to penetrate the marketplace.

Second, technical limitations are significant and breakthroughs cannot be assumed. The very low energy density of hydrogen imposes serious limitations for vehicles that need to travel long distances between refills. Storing enough hydrogen in a tank small enough to fit in a car requires the fuel to be compressed under very high pressure, or somehow stored in a solid form. In any case, storage limitations suggest hydrogen is probably not suited for vehicles like long-haul trucks or vehicles operating in non-urban areas.

Third, deeper analysis of the total energy balance for producing, transporting and storing hydrogen suggests that other alternatives could be cheaper, more sustainable and have lower total GHG emissions.[10] While a hydrogen mobility scenario remains a possibility, we think alternative scenarios may play at least as big a role and may prove more feasible, especially in the near- and medium-term.

Achieving 75-85% lower GHG emissions from the mobility sector cannot be reached overnight. It will take time to develop the infrastructure, planning systems and markets that can accommodate no-carbon, low-carbon energy carriers for use in transportation (and other mobility vehicles, such as construction equipment). This requires, quite simply, a wholesale transformation of the energy sources used for mobility. It means, if one assumed no growth in VMT and fuel economy stayed the same as it is now, we would need to shift to fuels or other energy carriers that emit no more than 25% of their current levels. While we think there can be large improvements in fuel economy, we do not assume VMT will decline from today's levels. As such, our best guess is that future transportation energy carriers need to reduce their net GHG emissions to between 0% - 20% of levels from today's conventional fuels.

We discuss in other parts of this chapter what progress toward the sector-wide 75% reduction target can be made by setting tailpipe emission standards, promoting more fuel efficient vehicles, addressing vehicle miles traveled. In this section, we discuss recommendations to:

- reduce tailpipe emissions from all vehicles by establishing state and provincial fuel standards that require gradually lower net carbon content in fuels over time;
- promote the production of sustainable, lower carbon fuels from biomass sources;
- explore the expansion of electric mobility infrastructure.

---

[10] Potential limitations of hydrogen gas in mobility applications are explored in some detail in *"The Future of the Hydrogen Economy,"* by Ulf Bossel, Baldur Eliasson and Gordon Taylor, April 2003 and *"Toward a Hydrogen Economy,"* a special section at pages 957 – 976 of Science, Vol 305, 13 August 2004. *See also*, Pew Center on Global Climate Change, "Reducing Greenhouse Gas Emissions From U.S. Transportation," prepared by Greene, D.L., Schafer, A., 2003, p. iv.

6.1 Establish a Declining Net GHG Fuel Standard

Summary

We recommend that each jurisdiction adopt fuel standards that promote commercialization of lower carbon transportation fuels on a net GHG basis.

Implementing this recommendation will entail:
- improving the accounting of the net lifecycle GHG emissions from competing types of fuels;
- developing a certification process by which net GHG emissions factors are assigned to each class of fuel and each production/distribution process;
- instituting a declining average net GHG standard (per unit of energy) for fuels sold in each jurisdiction.

Cellulosic ethanol and synthetic biofuels are two categories of biofuels that hold very high promise although they have not yet been commercialized. Comprehensive lifecycle analysis to date suggests that cellulosic ethanol emits about 52% to 88% fewer GHG emissions (depending on assumptions and inclusion of land use change) than using an equivalent amount of energy from petroleum-based gasoline. Synthetic fuels, if made from a mix of biomass and fossil fuels combined with carbon capture and sequestration, could have significantly higher net GHG benefits than cellulosic ethanol. The net GHG of these two fuels compare very favorably with regular corn ethanol and biodiesel, both of which are projected to drive such significant levels of land conversion and other production-related GHGs that they are unlikely to deliver climate benefits.

The projected emissions benefits of a net GHG gasoline standard could be in the range of 3.7 million metric tons of CO_2e by 2020 if lower net GHG fuels could be commercialized and deployed into the marketplace quickly. By 2050 the benefit could rise to as much as 17 million tons of CO_2e. Instituting net GHG standards for other fuels, such as diesel fuel (and also home heating oil) could increase these reductions further.

Displacing petroleum-based fuels has collateral benefits as well, including reducing our reliance on imported oil and providing a significant opportunity to build a new regional biofuels industry.

Opportunity

All fuels are not created equal. A gallon of gasoline does not have the exact same energy content as a gallon of ethanol. Moreover, the amount of GHG emissions associated with the extraction, refining and transportation of a unit of energy contained in gasoline is different from the emissions associated with farming, processing and transporting one unit of energy in ethanol. To make a meaningful analysis of any fuel's impact on climate, it is necessary to factor in the full spectrum of GHG emissions associated with the fuel's production and transportation and impacts on land use, and to compare the net GHG emissions associated with making a unit of energy.

Cellulosic ethanol and synthetic biofuels are two categories of biofuels that hold very high promise although they have not yet been commercialized. Comprehensive lifecycle analysis performed to date suggests that cellulosic ethanol emits about 52% to 88% fewer GHG emissions (depending on assumptions and inclusion of land use change) than using an equivalent amount of energy from petroleum-based gasoline. Table 2.1 compares the net GHG emissions results from recent studies for typical corn ethanol, cellulosic ethanol, and biodiesel in relation to gasoline and diesel. The results are quite different and seem to mostly be driven by assumptions about land conversion and emissions associated with fertilizer use in the case of biodiesel.

Table 2.1: Comparison of Recent Studies of Net GHG Emission Reductions from Fuels

Boundary	Source	Fuel Type	Net-GHG Emissions Reduction (%, positive numbers indicate lower emissions) Low		High
References are Gasoline and/or Diesel				0%	
Life Cycle Fuels Analysis (with land use impacts)					
	Delucchi, 2006 Draft	Corn Ethanol	-6%		2%
		Cellulosic Ethanol		52%	
		Biodiesel		-53%	
Life Cycle Fuels Analysis (without land use impacts)					
	Farrell et al, 2006	Corn Ethanol	-2%		13%
		Cellulosic Ethanol		88%	
	Hill et al, 2006	Corn Ethanol		12%	
		Cellulosic Ethanol		High	
		Biodiesel		41%	

Sources: M. Delucchi, 2006, *Lifecycle Analysis of Biofuels - Draft*
A.E. Farrell et al, 2006, "Ethanol Can Contribute to Energy and Environmental Goals," *Science* V. 311 (506-508)
J. Hill et al, 2006, "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," *PNAS* Vol. 103 No. 30

All of the studies identify ethanol from corn as having little to no net GHG emissions benefits. Factoring land use changes into the equation makes corn ethanol look like a poor tool for reducing GHGs. Cellulosic ethanol appears to have significant benefits, although the estimate of benefits are different (52-88%) with land use conversion again having a large impact on results.

As noted above, synthetic fuels, when made from a mix of biomass and fossil fuels in conjunction with carbon capture and sequestration, show technical potential to deliver significantly higher net GHG benefits than even cellulosic ethanol.

Displacing gasoline with alternative fuels may have several collateral benefits. It can reduce our reliance on imported oil and provide a significant opportunity to build a new regional biofuels industry (discussed further under the next recommendation). Perhaps most important, successful commercialization of local biofuel production would position the region's landowners, fuel producers and consumers to profit if or when transportation fuels became federally regulated for carbon content, as we expect they will.

The ideal policy approach to promoting lower-carbon fuels is to establish a framework that is not biased toward any particular fuel or technology, but which accommodates the entry of new alternative fuels (and vehicles and transportation infrastructure) as they are commercialized, and that makes a full accounting of the net climate impacts of each fuel.

One concept for promoting lower carbon fuels is a cap-and-trade system, which could regulate the average carbon content in transportation fuels. A cap-and-trade mechanism has been successfully used to promote lower nitrogen oxide and sulfur emissions from power plants in the U.S., and is currently in operation to promote lower carbon emissions from smokestacks in European Union countries complying with their Kyoto obligations. In the context of fuels (as opposed to smokestacks), a cap-and-trade approach might operate by requiring that:

> each … facility that produces, blends, refines, sells, or imports gas or liquid fuel used for transportation fuel shall submit 1 tradable unit for each unit of product the covered

facility sells that will produce 1 metric ton of greenhouse gases, measured in units of carbon dioxide equivalent.[11]

A cap-and-trade system for transportation fuels is an elegant solution to complement regulation of carbon from smokestacks, thereby achieving a more comprehensive, market-based approach to promoting clean energy alternatives across the entire economy. It also promotes a more level playing field among all transportation energy carriers (notably helping electricity, which is expected to have its production regulated by a carbon cap through a regional or national carbon regime). However, a cap-and-trade mechanism is one that may not be appropriate for implementation in a small geographic area (let alone in an individual state or province). In addition, any cap-and-trade program should address the issue of net emissions by fuel type and not just emissions at the point of combustion.

Another approach that can achieve a similar result is a Renewable Fuel Standard (RFS). At the time of this writing, six states in the U.S. have adopted laws requiring gasoline sales to contain a minimum percentage of renewable fuel (ethanol or biodiesel) content, as a means for promoting biofuel production.[12] Quebec's Climate Change Action Plan for 2006-2015 announces that the province will establish a 5% ethanol requirement in motor fuel sold beginning in 2012, estimating that this will reduce the province's consumption of gasoline by 300 million litres.[13]

While the RFS approach applied in these states and provinces should help commercialize the production and distribution of ethanol or biodiesel generally, the requirement will do little to achieve climate benefits as long as it fails to differentiate between production processes with higher and lower net GHG emissions and does not fully assess all climate related impacts of the RFS.[14] Also, a basic RFS will do nothing to commercialize cellulosic ethanol or synthetic biofuels that may emerge as lower-carbon alternatives. None of the existing or proposed state RFS mandates have provisions to factor in the net GHG emissions of the fuel's production.

Implementation

Because a cap-and-trade approach for fuels is less suitable for implementation at the level of an individual state or province, and a simple RFS will not achieve the goal of promoting the development of no- or low-carbon fuels, we recommend adoption of a fuel standard based on net GHG emissions per unit of energy. A similar standard could also be applied to other non-transportation fuels such as home heating oil.

---

[11] Strong Economy and Climate Protection Act of 2006, Working Draft, proposed by U.S. Sen. Feinstein, Sec. 107(a)(2)(A).

[12] *See*, Green Car Congress, http://www.greencarcongress.com/ethanol/index.html , reporting that Iowa, Louisiana, Minnesota, Montana, Hawaii, and Washington have adopted Renewable Fuel Standards, usually requiring a minimum production level be met before the standard is triggered.

[13] Government of Quebec, *Le Québec Et Les Changements Climatiques, Un Défi Pour L'avenir: Plan D'action 2006 – 2012*, June 2006, p. 22.

[14] For example EU and Latin American renewable fuels standards are driving the conversion of forests in Southeast Asia to palm oil plantations and of South American rainforests to soy production. While these effects were not intended, they are occurring as global agricultural systems adjust to meeting these mandates. *See, e.g.*, "The most destructive crop on earth is no solution to the energy crisis," George Monbiot, *The Guardian*, December 6, 2005; Fred Pearce, "Forests paying the price for biofuels", *NewScientist.com news service*, 22 November 2005; and Marcela Valente "ARGENTINA: The Environmental Costs of Biofuel", *Inter Press Service News Agency*, http://www.ipsnews.net/news.asp?idnews=32959. Conversion of land from one use to grow biomass feedstock also can have significant climate impacts that go beyond net GHG emissions effects. *See*, *e.g.*, "The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy", Gregg Marland, Roger A. Pielke, Sr., *et al.*, *Climate Policy* 3 (2003), 149-157.

The basic concept of this policy is as follows:

- Analytic tools would be developed to afford a more complete accounting of net climate effects from competing types of fuels and fuel (energy carrier) production and distribution methods on a net GHG per unit of energy basis (gCO_2e/MJ).
- A certification process would be established to assign a net GHG emissions factor to each class of fuel and production/distribution processes.
- Distributors of transportation fuels in a state or province would be required to achieve an average annual net GHG standard per unit of energy (gCO_2e/MJ) for each basic type of transportation fuel sold in the jurisdiction. The GHG standard would start slightly below the current average (gasoline and diesel) and decrease over time according to a set schedule.
- The standard would be met by increasing the portion of total sales from lower GHG fuels each year and be based on a distributor's average net GHG of a given automotive fuel (*e.g.*, gasoline, diesel fuel) sold in the state over the course of a year, allowing the distributor to balance the sales of various blends with straight gasoline sales however they prefer. One distributor's method of compliance might be to blend 1% cellulosic ethanol with 99% conventional gasoline across all of their sales. Another distributor's method of compliance could be achieved by selling a small quantity of 85% cellulosic ethanol to consumers with flex vehicles while meeting the balance of supply needs with conventional gasoline.
- Default values would be set for each basic fuel type.
- Chain of custodies from manufacturer to dealer would be required for fuels that did not use default fuel values.
- A certificate based trading scheme could be considered to allow further flexibility and trading among dealers.

When devising a fuel standard by which to compare net GHG impacts, it is critical to consider the following:

First, current crops of biomass (*e.g.*, corn, soybeans, sugarcane, rapeseed, palm, trees/wood) have competing uses in the economy, including food supply. Switching some of the existing supply over to increased production of biofuels can have significant impacts on the supply and price of these commodities.

Second, new biofuel supply has to come from somewhere. Increasing biomass production could have major impacts on land use. Except for biofuels made from waste streams (including wood residues), significantly increasing biofuel supply from crops will necessarily result in new land being converted to cultivation. Either new land will be converted to cultivate crops dedicated for biofuel supply, or land will be converted to cultivate crops that were formerly grown elsewhere (but have been displaced there to grow crops dedicated for biofuels). In both cases, the GHG impacts of converting land to cultivation must be added to the GHG emissions factor for the resulting biofuel. Most analysis of the net GHG impacts of different biofuels has simply assumed some amount of the current cropland becomes dedicated to producing crops for biofuels, but does not factor in the GHG impacts of converting new land.

Third, even if we converted large quantities of land to cultivate biofuels, the resulting fuel output would only constitute a small fraction of our total North American transportation energy demand.[15]

While biomass will be an important contributor to addressing the energy needs of the region and meeting climate change objectives, it will also become an increasingly valuable commodity. This suggests

[15] Hill et al, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," National Academy of Science, *PNAS*, vol. 103, no. 30, July 25, 2006, p. 11206, finding "Even dedicating all U.S. corn and soybean production to biofuels would meet only 12% of gasoline demand and 6% of diesel demand."

that we focus on policies that put biomass to its highest and best use, as measured in economic sustainability, profits, and benefits to the environment with carbon assessed on a net GHG basis.

At the present time, the most promising paths to producing transportation biofuels that are sustainable and provide the biggest net reduction in GHGs over the full lifecycle of the product are (a) cellulosic ethanol and (b) synthetic fuels produced from biomass.

As described more in the next recommendation, cellulosic ethanol production has not yet reached commercialization. Nonetheless, even the most conservative and comprehensive lifecycle analysis to date suggests that the full lifecycle analysis of cellulosic ethanol emits about 52% fewer GHG emissions than using an equivalent amount of energy from petroleum-based gasoline.[16] This compares very favorably to "typical" corn ethanol production (used to make most ethanol today) which, assuming significant new land would need to be converted to cultivation, will not reduce net GHG emissions compared with gasoline use.[17]

The other promising path – producing synthetic fuels using biomass – is also described more in the next recommendation. A variety of approaches, including gasification and/or fractionation, can convert biomass into fuels suitable for use in transportation vehicles. One lifecycle analysis has suggested that the net GHG of biomass used to make synthetic fuels, when combined with carbon capture and sequestration, could have two to three times greater net GHG reductions than cellulosic ethanol.[18]

Figure 2.8 projects emissions based on a hypothetical net GHG fuels standard for gasoline sales. Note that this projection is heavily impacted by changes in vehicle miles traveled and vehicle emissions and efficiency standards. This assessment assumes that gasoline consumption in the NE-EC region is held constant through other policies.

---

[16] Delucchi, p. 18, Table 3, assuming switchgrass as a feedstock.

[17] *Ibid.* For comparisons of net GHG impacts that do *not* factor in extensive new land conversion or other policy price impacts, *see*, Farrell *et al.*, "Ethanol Can Contribute to Energy and Environmental Goals," *Science*, Vol. 311, Jan. 2006, p. 506-508; *see also*, Alex Farrel, presentation to the California Air Resources Board Chairman's Seminar on May 17, 2006 http://www.arb.ca.gov/app/calendar/cal_wbcst.php and ftp://ftp.arb.ca.gov/carbis/research/seminars/farrell/farrell.pdf and also, Hill *et al.*, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," 2006, p. 11207, which admonished readers: "It is important to note that these estimates assume these biofuels are derived from crops harvested from land already in production; converting intact ecosystems to production would result in reduced GHG savings or even net GHG release from biofuel production."

[18] Williams, R.H., "Importance of CO2 capture and storage for bioenergy," Memo, March 16, 2006, Table 3, p. 9.

Figure 2.8: Net GHG Fuels Standard for Gasoline with Estimated GHG Emissions Benefits

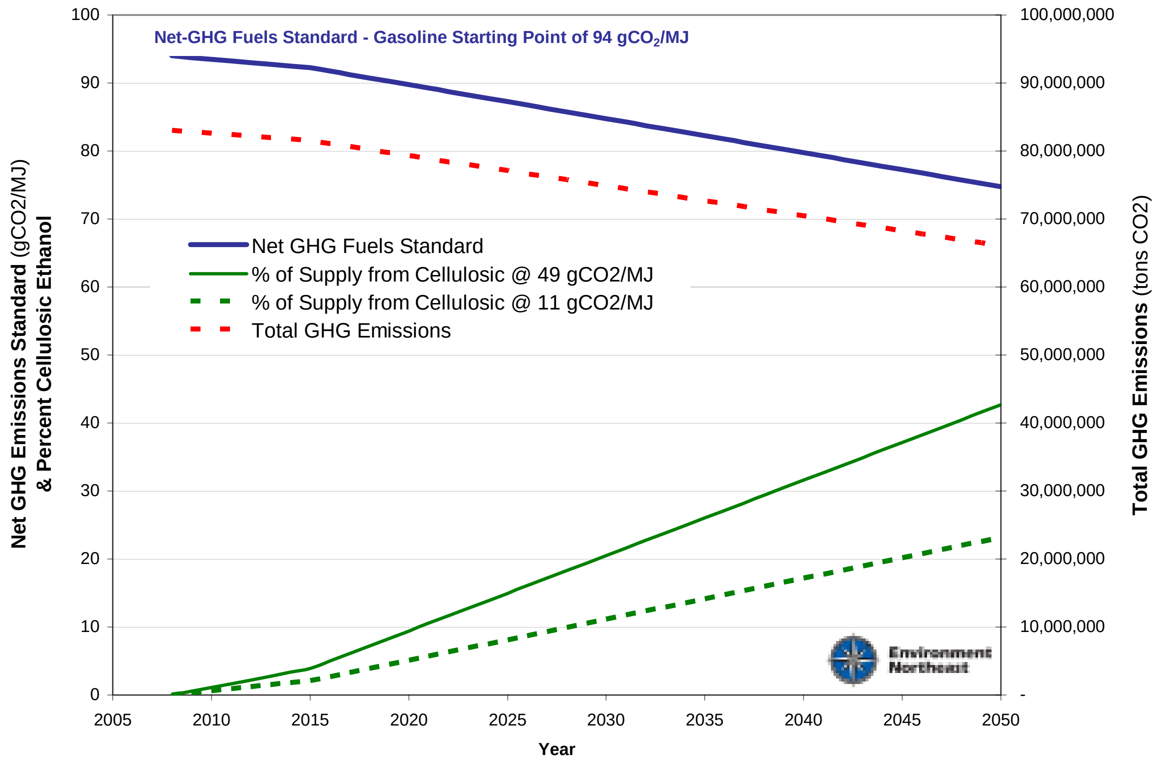


Figure 2.8 illustrates the impact of the net GHG emissions estimate for the cellulosic ethanol being used. If the higher net emissions number is assumed then a larger percentage of ethanol would be needed to achieve the standard. The setting of the standard would need to be done with potential fuels in mind to ensure that the requirement could be reasonably met with existing land resources and fuel technologies. The projected emissions benefits by 2020 of the gasoline standard shown above would be in the range of 3.7 million metric tons of CO_2e and 17 $MMTCO_2e$ by 2050. In reality, a target would likely need to be set for a 10 to 20 year period and then adjusted as needed. Adding other fuels such as highway diesel fuel and non-road diesel fuel/home heating oil could allow these benefits to increase significantly, assuming there are fuels available at a lower emissions level per unit of energy that can be substituted for distillate fuels.

Currently, many states regulate fuel standards as a means of complying with their obligations to meet National Ambient Air Quality Standards for ozone. The reformulated gasoline (RFG) standards required by some states directed distributors to use a blend of the additive MTBE as a way of reducing automobile NOx emissions. However, problems of contamination in groundwater have caused many states, like Connecticut, to replace MTBE with ethanol, resulting in a 10% ethanol blend.[19]

Review of the Connecticut regulations for reformulated gasoline reveals a rich framework for implementing, monitoring and enforcing a fuel standard. States (and provinces) seeking to implement a net GHG fuel standard would do well to build on existing frameworks used to ensuring compliance with ozone State Implementation Plans. This framework includes extensive, detailed provisions on inspection, sampling and labeling of fuels, registration of vendors, retention of shipping records, reporting, and enforcement authority.[20] This framework also relies on coordination with other jurisdictions, outreach, and education and interagency coordination to run smoothly.

---

[19] *See*, *e.g.*, Regulations of Connecticut State Agencies, 22a-174-128.
[20] §14-327 of the Connecticut General Statutes (CGS).

6.2 Explore Pathways to Develop Low-GHG Biofuels in the Region

Summary

We recommend that states and provinces in the region work to commercialize sustainable, low-GHG production of transportation fuels using woody biomass and grasses. The region should establish a regional initiative to collaborate on research and development of new biofuel technologies and processing plants and to scope out the path ahead for developing a local biofuels industry and markets for biofuels products. Among the tasks for this collaborative are to evaluate:

- pathways for converting indigenous biomass resources into useful energy carriers;
- total lifecycle GHG impacts of competing biomass conversion pathways;
- market potential for competing biofuels;
- suitability of existing siting and permitting regulations to accommodate new biorefineries and local environmental/community concerns;
- legal and economic potential for biorefineries and/or landowners to receive tradable "offsets" under a regional or federal carbon cap-and-trade regime;
- policy options employed in other states/provinces, and internationally, to help develop a new sustainable biofuels industry.

In addition to instituting a declining fuel GHG standard (described above), states and provinces should consider establishing financial incentives and grants to help develop this industry.

Biofuels made from woody biomass have the potential to result in lower lifecycle GHG emissions. The NE-EC region is home to a very significant forest products industry and an abundant supply of woody biomass or biomass by-products (*e.g.*, black liquor).

Opportunity

There are several types of transportation fuels made from woody biomass that are of interest for meeting climate and sustainable energy objectives in the NE-EC region:

- synthetic fuels (or gases) – produced by converting biomass using pyrolysis, gasification or fractionation (or some combination of the three);[21]
- cellulosic ethanol – produced by breaking down the cellulosic fiber of biomass using enzyme technology and then fermenting it into ethanol.

The NE-EC region does not have the abundant corn or sugar cane fields that farmers use to make commercial-scale ethanol in the Midwest U.S. and Brazil, respectively. While there is some amount of biodiesel that could be made from conventional processes using soybeans, the benefits of this fuel are not clearly understood from a climate, environmental or sustainability standpoint.[22] Biofuels made from

---

[21] As noted in the prior recommendation, very low (and possibly even negative) net GHG synthetic fuels can also be produced by combining biomass and fossil (*e.g.*, coal) feedstocks with commercially available gasification and synthetic fuels production, and then applying carbon capture and sequestration. Recent analyses suggests that this process can be used to make synthetic gasoline or diesel fuel with significantly lower net GHG emissions than cellulosic ethanol. *See, e.g.*, Williams, R.H., "Toward Ultra-Low GHG Emissions for Synfuels," DoD Clean Fuels Initiative, US Department of Energy, March 2006 and Williams, R.H., "Importance of CO2 capture and storage for bioenergy," Memo, March 16, 2006,

[22] Biodiesel made from soybeans in North America typically emits more GHG in the farming, processing and transporting of the fuel than the GHG it displaces from regular diesel fuel. *See e.g.*, Delucchi, "Lifecycle Analyses of Biofuels -- Draft Manuscript," May, 2006. Even if the net GHG calculation were to become favorable over time, there is an absolute limitation on the quantity that could be domestically produced. Biodiesel from recycled cooking oil gives a benefit from a net GHG standpoint, but there is only enough to power the occasional individual vehicle or small fleet. To mass produce enough soy-biodiesel to displace just one-quarter of today's diesel consumption (i.e., using biodiesel in place of petroleum products in the farming and production process), would require putting 400 million acres of U.S.

woody biomass or grasses, on the other hand, have the potential to result in lower lifecycle GHG emissions, and the NE-EC region is home to a very significant forest products industry and an abundant supply of woody biomass as well as some pasture and grassland. By way of illustration, it is estimated that 26 million acres of the Northern Forest in the states of Maine, New Hampshire, Vermont and New York is forested territory. In Maine alone, there is a very large supply of biomass from commercially managed timber operations. (See Table 2.2.)

Table 2.2: Inventory of Maine Biomass

	Million Dry Tons/Year	% of Total Biomass in Maine
Total Biomass on Commercial Timberland	990	100%
Growing Stock	464	46.80%
Residue*	227.3	22.96%
Existing Bio-power	3.6	0.36%
Forest Residue** <$50/ton	1.5	0.15%

Source: River Valley Biomass Refinery Market Study, MicroChem Technologies, Inc., Jan. 2006, p. 9.

Notes: * Includes upper stem, foliage, branches, cull trees and dead trees, but not stumps and roots, saplings and shrubs.
** Estimate of the amount of residue that could be harvested beyond the current annual use rate.

Environment Northeast

A strategic planning report prepared for the Fractionation Development Center of Maine indicates that by using Forest Residue resources alone, the state could develop a biorefinery industry capable of providing a variety of transportation fuels and thermal or electric energy using a three-stage plan.[23] Under one scenario, the report estimates that within 10 years the biorefinery industry could generate 650,000 tons of dimethyl ether (DME), an excellent synthetic fuel substitute for propane that has also been discussed as a possible replacement fuel to blend with diesel. The report concludes that, using the total residue resource of commercial forestry in the state, total production levels could reach 100 times the aforementioned estimate.

Another opportunity for making synthetic fuels from biomass is being explored by some paper manufacturing companies in North America. Black liquor is a by-product of the pulping process in paper mills. Currently, kraft paper mills generate steam for their industrial processes by burning the black liquor in Tomlinson recovery boilers, the majority of which "will reach the end of their 30-40 year lifetimes over the next 10 to 20 years."[24] When the time comes to replace these old boilers, paper mills will have an opportunity to install new gasification systems that can use the black liquor to make electricity or synthesized liquid or gaseous fuels, or process heat. This could potentially provide a new revenue stream for the paper companies or timber companies and reduce the mills' solid waste stream and air emissions at the same time.

Internationally, there is also increased activity to develop transportation fuels from woody biomass feedstocks. For example, using the gasification and Fischer-Tropsche process, engineers in Japan at the Biomass Technology Research Center (BTRC) recently demonstrated a laboratory-scale portable

---

cropland under cultivation of soybeans, effectively doubling total U.S. cropland. *See*, Heather L. MacLean, Lester B. Lave, Rebecca Lankey, Satish Joshi; "A Life-Cycle Comparison of Alternative Automobile Fuels", *J. Air & Waste Manage. Assoc.* 50:1769-1779. Biodiesel is most efficiently made from canola oil or palm oil, but large-scale development of these plantations has lately resulted in clearcutting of rainforests.

[23] River Valley Biomass Refinery Market Study, MicroChem Technologies, Inc., Jan. 2006. p. 23.

[24] Larson, E.D. et al, "A Cost-Benefit Assessment of Biomass Gasification Power Generation in the Pulp and Paper Industry," Princeton Environmental Institute, 8 October 2003.

biomass gasification system that can continuously produce synthetic diesel fuel from wood at a much higher level of efficiency than prior systems.

Production of synthetic compressed natural gas from woody shrub plantation (or other forest wood) feed stocks also appears to have the potential to have significantly less net GHG emissions than does gasoline or diesel fuel.[25]

While cellulosic ethanol has the potential to deliver much larger net energy output and greater net GHG reductions compared to regular corn ethanol (or biodiesel), the process for breaking down cellulose is still developing, and work remains to be done before it is commercialized. An additional challenge in commercializing this process is that the enzymes needed to break down cellulose are different for each kind of biomass feedstock. A company called Iogen, located in Ontario, is the only company in North America with a demonstration production plant that converts wheat straw to cellulosic ethanol using enzyme technology. At the time of this writing, the company is looking for a site in the Canada or the U.S. to build a full scale demonstration plant.[26]

States and provinces in the region would be well-served to build a better understanding of the barriers and opportunities facing the development of a biofuels industry. We know, generally, that these barriers include:

- in the case of cellulosic ethanol, the need for technology and process breakthroughs in manufacturing of the fuels for each kind of feedstock;
- incomplete understanding of sources and quantities of feedstock;
- incomplete understanding of the most profitable combination of outputs (fuels) and by-products and the market potential for those outputs;
- the need for significant capital investment;
- uncertainty about the criteria (environmental, etc.) for siting and permitting facilities and other infrastructure needed for biofuel manufacturing;
- various potential risks associated with use of new, unfamiliar technologies and processes;
- an immature market or lack of a market that fully values the climate benefits of net GHG reducing biofuels.

Implementation

To address these barriers, we recommend establishing a regional initiative to collaborate on research and development of new biofuel technologies and processing plants and to scope out the path ahead for developing a local biofuels industry and markets for biofuels products. This approach facilitates cost-sharing for studies and pilot projects, and is an efficient way to get the best information, analysis and opportunities out on the table in a timely manner. It could be modeled, though on a much larger scale, on the approach currently being used to study the feasibility of developing in-stream tidal power generation along the coastal states and provinces of this region.

An initial task of this collaborative should be to survey the literature about biofuels technology, net greenhouse gas impacts of biofuel production, and global initiatives to develop biofuel production industries and markets.

A second task is to recruit a suitable mix of participants in the collaborative and to establish a schedule of periodic meetings, a means of communication, a common mission and a list of objectives. We envision participation from:

[25] Delucchi, p. 18, Table 3.
[26] http://www.iogen.ca/.

- industry - timber companies, pulp and paper companies, other regional energy companies, large commercial agriculture operations, and chemical or refinery companies;
- government - state/provincial and federal officials representing such agencies as forest service, agriculture, transportation, natural resources, and environmental protection;
- independent experts from academia and consulting sectors;
- stakeholders representing such interests as natural resource use, sustainable agriculture/forestry, sustainable energy and environmental protection.

A third task is to establish a Biofuels Action Plan to evaluate the near-term opportunities for research, development and demonstration, and to commence implementation of that plan. On the research and development front, it will be useful to evaluate:

- the most promising pathways for converting indigenous biomass resources into useful energy carriers;
- the total lifecycle GHG impacts of competing biomass conversion pathways, including potential impact of land conversion dedicated to cultivating biomass and of competing policy options designed to promote biofuels;
- the market potential for competing biofuels, *i.e.*, gasoline substitutes, diesel fuel substitutes (as well as home heating oil substitutes), DME and other synthetic fuels, or hydrogen;
- the suitability of existing siting and permitting regulations to accommodate new biorefineries and local environmental/community concerns;
- the legal and economic potential for biorefineries and/or landowners to receive tradable "offsets" under a regional or federal carbon cap-and-trade regime;
- the menu of policy options employed in other states/provinces, and internationally, to help develop a new sustainable biofuels industry.

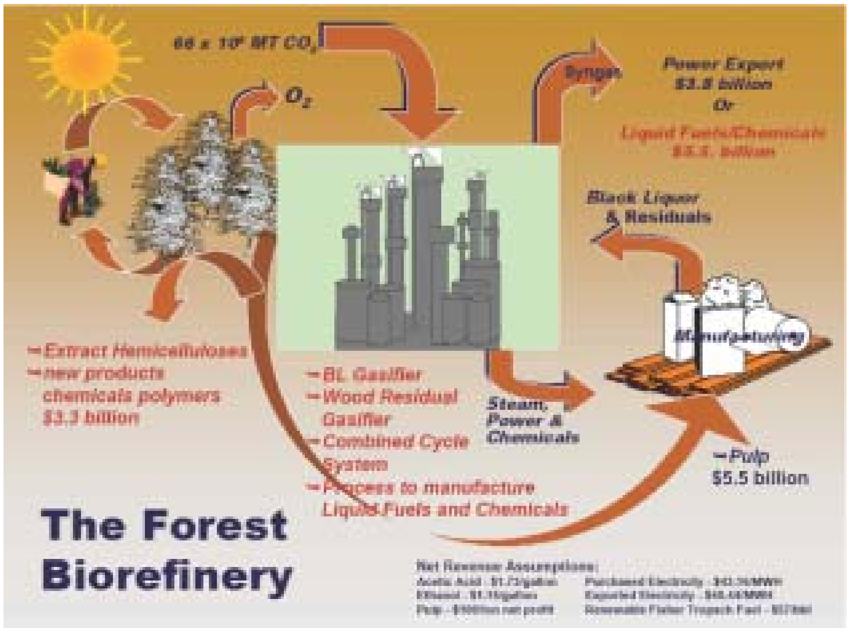
The concept of establishing a net GHG fuel standard that gradually requires lower carbon intensity per unit of energy (described above) is another possible tool to advance a biofuels market. Another step to develop the market includes developing accounting protocols to determine the lifecycle GHG emissions from competing biofuel production methods. Such accounting will be critical to making a fuel standard work, and could also help make net GHG reductions eligible for compensation in offset markets. One academic observer has suggested establishing a certification system that would grant third-party attestation (*e.g.*, "Certified Low-GHG Ethanol") in order to differentiate various biofuels products according to the feedstocks and production methods they use.[27]

A serious effort to develop biofuel markets may be aided by the establishment of financial incentives in addition to regulations such as fuel GHG standards.[28] Several financial incentives already exist at the federal level. In the U.S., for example, there are exemptions for biofuels from excise taxes and guaranteed loan programs for the construction of new biofuel plants.[29]

[27] Farrell, A., "Emissions from Fuel Ethanol: Separating the Confusion From the Uncertainties," presentation to the California Air Resources Board, May 16, 2006, p. 50.
[28] EPAct 2005 requires U.S. production increases in ethanol and biodiesel from 4 to 7.5 billion gallons by 2012. The European Parliament set a 5% requirement for biofuels blended with gasoline, adopted Directive 2003/30/EC.
[29] *See e.g.*, Energy Tax Act (Public Law 95-318).

Example: Maine Biofuels Research

Within the NE-EC region, there are early signs of progress in promoting biofuel development. For example, the idea of developing a "forest biorefinery" to commercialize production of synthetic fuels from woody biomass is gaining strong interest in Maine. The forest biorefinery moves away from the single product approach of a saw mill or a paper mill in favor of building new mills capable of making multiple products, squeezing as much productivity out of the biomass feedstock as possible by breaking the biomass down into its chemical components and processing these components into multiple commercial products.



Source: The American Forest & Paper Associations.

Some work has already begun in the region to explore the potential for developing biorefineries. The University of Maine recently put together more than $10 million in federal and state grants to kick off a research and development initiative designed to help industry develop an integrated forest biorefinery. The University plans to research the process of extracting chemicals from wood chips and shavings before they are made into pulp or oriented strand board (OSB), and studying how these bio-chemicals "could be sold as new feedstocks or used on-site to manufacture materials such as fuel ethanol, plastics and specialty chemicals…"[30]

Similar work by the Fractionation Development Center in Maine, noted above, has studied the feasibility of using forest products industry residues to make synthetic liquid fuels from forest residues and developed a three stage, regional strategy. There is strong interest now in taking the next steps to build the first generation of processing plants.

Example: Quebec Biofuels Support

In Quebec the Climate Action Plan released in June, 2006 proposes to establish a carbon tax on the wholesale sale of all hydrocarbons that is expected to generate about C$200 million. Not only will the carbon charge make net GHG-reducing biofuels look comparatively less expensive than higher-carbon conventional fuels, but the proceeds can be used to help commercialize biofuel production and cover the costs of researching and certifying net GHG balances of different biofuel production methods.[31]

---

30 University of Maine at Orono, Press Release, March 28, 2006.

31 Government of Quebec, *Plan D'action 2006 – 2012, Le Québec Et Les Changements Climatiques : Un défi pour l'avenir*, June 2006.

6.3 Explore the Expansion of Electric Mobility Infrastructure

Summary

We recommend that states and provinces work together regionally to plan, invest in and build the infrastructure necessary to accommodate increasing electrification of the transportation system.

As a first step, high-tech businesses and universities located in the NE-EC region should be encouraged to help develop vehicles (and vehicle systems) that make greater use of electricity.

Second, the region needs to develop a list of the issues that need to be addressed to accommodate electrification of the transportation system, and to develop a plan of action. A preliminary list of issues for consideration includes:

- impact on generation capacity;
- capacity of transmission and distribution lines;
- the impact on load curves and policy options for promoting preferred (off-peak) charging times;
- technical standards and building guidelines for charging devices placed at private residences, commercial vendors and public places;
- pros and cons of competing options for distributing electricity to electrified roadways or guideways.

A third step is to develop plans and procedures to build and manage the necessary infrastructure.

Plug-in electric hybrid vehicles could cut GHG emissions by about 50% compared to conventionally powered vehicles. Fully electrified vehicles, including trains, freight carriers, or passenger vehicles, using electricity from low- or no-carbon sources, can theoretically reduce GHGs by 85-100% compared to a conventional gasoline or diesel fueled vehicle.

Opportunity

Electricity has significant potential as an energy carrier for the mobility system of the future. Electric motors have no tailpipe, emitting no GHGs on board the vehicle. There are various ways to generate electricity (to power the electric propulsion system) that have no-carbon or low-carbon emissions.

Expanding electric mobility in the NE-EC region is contingent on making progress on two fronts:

- developing electric powered vehicles that meet the needs of consumers in terms of comfort, functionality, range and cost;
- building and operating the infrastructure needed to deliver electricity to charge electric powered vehicles.

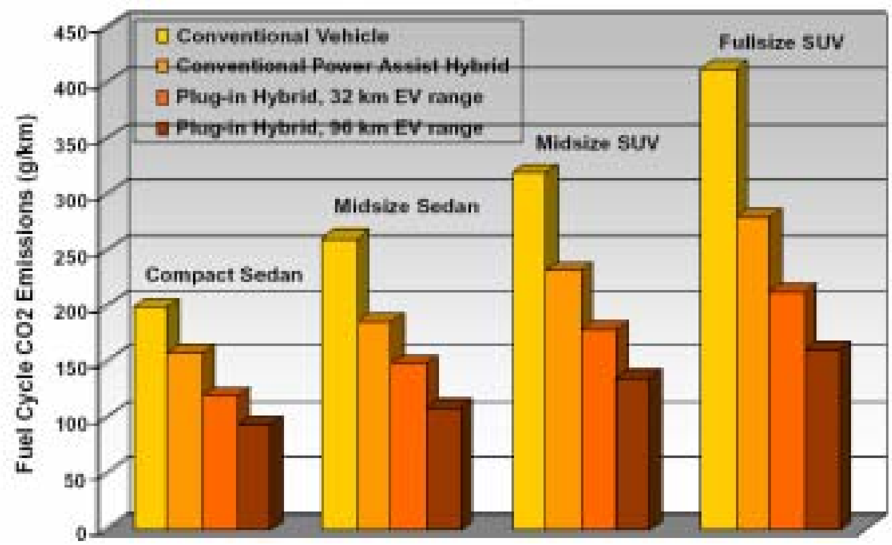
Developing Electric Powered Vehicles

The concept of powering vehicles with electric motors is not new. In the early 20th century cars were built to run on heavy stacks of lead acid batteries, and again in the 1990s the idea was pushed with such policies as the Zero Emission Vehicle (ZEV) mandates. One of the main reasons these electric-only vehicles did not penetrate the marketplace is that the distance they could travel between charges (the range) was quite limited, and consumers would not tolerate this inconvenience.

In the context of light vehicles, this problem has been partially addressed by the advent of the hybrid engine. In gasoline-electric hybrid electric vehicles (HEV), electricity is produced through regenerative braking and stored on-board in batteries. The batteries deliver electricity to an electric motor that supplements the main propulsion system in the vehicle, a gasoline or diesel internal combustion engine. In this way, the vehicle can achieve both the extended range delivered by high-energy density fuels like gasoline or diesel, as well as improved fuel economy due to the electric assistance.

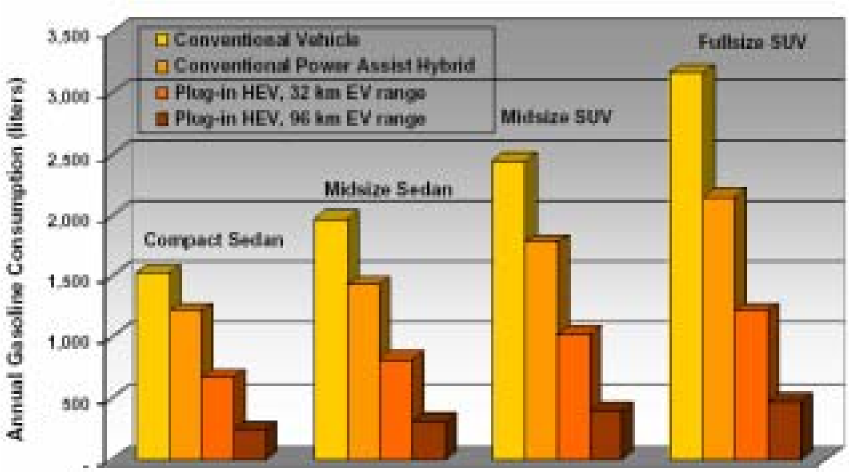
Recently, the gasoline-electric hybrid concept has been modified to address the vehicle range issue while potentially achieving vast improvements in GHG reductions. The “Plug-in hybrid” concept gives the electric motor the main job of propulsion in the vehicle while reserving for the internal combustion engine the role of backup or supplemental power provider. The increased duties of the electric motor require more energy than can be regenerated on-board from braking. Thus, more batteries are added and they are charged by periodically connecting to the electric grid, much like the many rechargeable household items commonly in use, which has led to the moniker “Plug-in” hybrids. Figures 2.9 and 2.10 illustrate the relative GHG emissions of conventional engines, conventional hybrids, and two types of Plug-in hybrids across four sizes of light vehicles and the relative gasoline consumption of these different engine types, respectively.

Figure 2.9: Fuel Cycle CO_2 Emissions for Various Vehicles.[32]



Source: Duvall, EPRI (2005).

Figure 2.10: Annual Gasoline Consumption for Various Vehicles[33]



Source: Duvall, EPRI (2005).

---

32 Dr. Mark Duvall, “Plug-In Hybrid Electric Vehicles,” Electric Power Research Institute, presented at The Seattle Electric Vehicle to Grid (V2G) Forum, June 6th, 2005, p. 8. 32 kilometers equals about 19 miles, and 96 kilometers equals about 57 miles. The ICE backup engine would allow additional range on top of the EV range.

33 *Ibid.*, p. 9.

Recognizing that a Plug-in hybrid would not be suitable for every consumer, still it seems intuitive that a very large percentage of consumers in the non-rural areas of the NE-EC region could satisfy their daily driving needs using a Plug-in hybrid with a range between 30 and 100 miles. If correct, every Plug-in that displaced conventional vehicles of the same size could cut GHG emissions by about 50%.

A different way to solve the range limitations of electric vehicles (or more specifically, batteries) is to bring the electricity to the motor, as is commonly done for public transportation systems with electric trains, trolleys, and buses as well as with some short-distance freight movement systems.[34]

For example, the Metro-North commuter rail line that connects commuters from New Haven, Connecticut to New York City relies on Electric Multiple Units (EMUs), delivering electricity to motors in each car by means of either a third rail under the vehicle or an overhead catenary wire.[35] Parts of the Metro-North system are designed to accommodate both electric motors and diesel engines.

Example: MBTA Silver Line

Construction of the new Silver Line by the Massachusetts Bay Transportation Authority (MBTA) relies on hybrid buses that can switch between electric motors fed from an overhead catenary wire, or on-board regenerative braking, or on-board diesel engines. This is made possible by a dual-mode electric/diesel-electric propulsion system that was placed in the new low-emission, 60-foot-long articulated buses. Another innovative Bus Rapid Transit (BRT) feature of the Silver Line is the establishment of a dedicated right-of-way through the tunnel that connects the city's main train station to the South Boston Waterfront and Logan airport.[36]

Developing Electrified Transportation Infrastructure

In recent years, transportation planners, academics and enthusiasts have begun to theorize ways in which the electrification of mass transit vehicles could be replicated for individual passenger vehicles. Their goal is to develop a transportation system that reduces traffic congestion, achieves long-term GHG emission targets, reduces our reliance on imported energy, maintains safety and satisfies our desire for individual freedom and flexibility. In other words, they seek to design a system on which motorists could drive from door to door in their own cars, at any time.

Whether on a dedicated platform ("guideway") or rail, or a dedicated lane on an existing highway, the most flexible concept being discussed consists of an electrified route on which passenger vehicles, (as well as freight) can be propelled by on-board electric motors until they wish to exit the system. Once they exit, they can drive to their final destination using electric power from on-board batteries or by switching to an internal combustion engine as in the Plug-in HEV concept.[37] This is referred to as a "dual mode" transportation system.

It is worth noting that whether electricity is used to charge plug-in batteries or to run motors through some connecting power line, there may be as much as 50% energy loss experienced from the primary energy conversion (*e.g.*, making electricity at the power plant) to the line losses in the transmission and

---

[34] *See generally*, Drake, A.S., "Electrification 101: Electrification of Transportation as a Response to Peaking of World Oil Production," Commentary, updated 2005/12/20 at Light Rail Now!, http://www.lightrailnow.org/features/f_lrt_2005-02.htm.
[35] http://en.wikipedia.org/wiki/Multiple_unit.
[36] http://www.allaboutsilverline.com/waterfront_service.asp.
[37] *See*, *e.g.*, McHenry, B.A., "e-Guideways: More Realistic than the 'Freedom Car,'" March 2004, updated 3/16/06 http://www.discussit.org/transportation/article/index.htm; Stephan, C.H, *et al.*, "A Program for Individual Sustainable Mobility," unpublished paper presented at Global Powertrain Congress, September 2003; Reynolds, F.D., "The End of Traffic Jams: A Transportation System for the Future,"
February 2001 http://faculty.washington.edu/jbs/itrans/index.html, originally published in the *The Futurist*, September-October, 2001, pp. 44-51.

distribution of that electricity as it travels to its final destination. While electric transportation will lower GHG emissions at the tailpipe and can certainly reduce reliance on imported energy, its ultimate impact on climate will depend on the source of the electricity and how great the efficiency gains and losses are through the process compared to on-board combustion of gasoline or diesel.

Capturing the potential GHG emission reductions through increased electrification of the transportation sector is contingent on:

- convincing manufacturers to design and build production-scale vehicles (and energy storage systems), that are cost-competitive with conventional vehicles over the life of the vehicle;
- delivering no-carbon and low-carbon electricity to the vehicles where and when it is needed.

Implementation

Electric Powered Vehicles

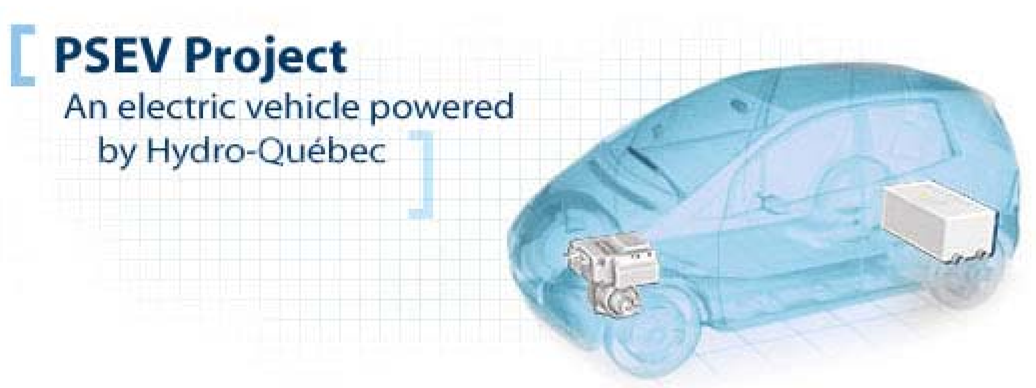
For passenger vehicles, progress must be made in the development of vehicles that are better suited (*e.g.*, lighter weight) to electric motor drives and in energy storage systems.

We expect that some of this kind of work may be within the competence of high-tech businesses and universities located in the NE-EC region, but acknowledge that most of the automotive manufacturing industry is located outside this region.[38]

Example: Hydro Quebec Electric Vehicle Program

In Quebec, the utility Hydro-Quebec has formed IndusTech, a wholly owned subsidiary, to pursue opportunities in the electric vehicle market. IndusTech's PSEV (Propulsion Systems for Electric Vehicles) project works in partnerships with manufacturers of electric vehicles and is developing two proprietary components for potential use in such vehicles.

One component is a drivetrain system designed, developed and produced by another subsidiary, TM4, to be used in Peugeot's new concept vehicle, the Quark. The Quark is an all-terrain vehicle driven by independently operating electric direct-drive motors. One motor is located in each wheel. Avestor is a second subsidiary that, in partnership with Kerr-McGee, aims to develop battery storage devices for possible use in electric vehicles.[39]



Source: Hydro-Quebec

[38] *See*, *e.g.*, MIT's Sloan Automotive Laboratory at http://web.mit.edu/sloan-auto-lab/; *see other examples at* MIT Center for Transportation and Logistics, http://ctl.mit.edu/; Texas A&M University's Center for Energy, Environment and Transportation Innovation (CEETI), http://www.ceeti.org/ ; UC Davis Institute of Transportation Studies (ITS-Davis) http://www.its.ucdavis.edu/.

[39] Hydro-Quebec, "Moving Forward: Sustainability Report," 2004 and http://www.hydroquebec.com/technology/industech/index.htm.

Electrified Transportation Infrastructure

Another area of focus should be developing the infrastructure that would be needed to support increased electrification of the transportation system.

The first step is to develop an understanding of the electricity grid's capacity to accommodate new transportation loads. We urge the utilities, grid operators and policy makers in the region to begin reviewing now the potential demands that would be placed on the system by increased electrification of the transportation system. They, together with key stakeholders and academic experts, should work to develop a list of the issues that need to be addressed to accommodate electrification of the transportation system, and to develop a plan of action. A preliminary list of issues for consideration includes:

- impact on generation capacity;
- capacity of transmission and distribution lines;
- the impact on load curves and policy options for promoting preferred (off-peak) charging times;
- technical standards and building guidelines for charging devices placed at private residences, commercial vendors and public places;
- pros and cons of competing options for distributing electricity to electrified roadways or guideways (*e.g.*, catenary wire, 3rd rail, MagLev, etc.).

A second step is to develop plans and procedures to build and manage the necessary infrastructure. The biggest challenge is likely to be developing long-term plans that will attract sufficient political and financial support to make binding decisions and begin implementation of the project. The magnitude of this effort could be on the order of other, very large, complex infrastructure projects like the U.S. Interstate Highway System, the extension of high-speed cable connections or the development of the satellite communications system. But as the success of those initiatives has proven, it can be done.

Moreover, transportation infrastructure and electric utility matters fall squarely within the jurisdiction of states (and provinces). For example, in the U.S. and Canada it is the states and provinces that regulate utility distribution systems, tariffs, and interconnection standards. In the U.S., it is the states that determine where to spend federal highway funds, and it is the states that have bonding authority to finance new bridges, tunnels, and roads. Because both electric utility grids and highway systems are inherently interconnected across state and international boundaries, this kind of long-term planning, cost-sharing and execution is likely to be more successful if it is regionally coordinated.

Priority 7: Reduce GHG Emissions from Light Vehicles

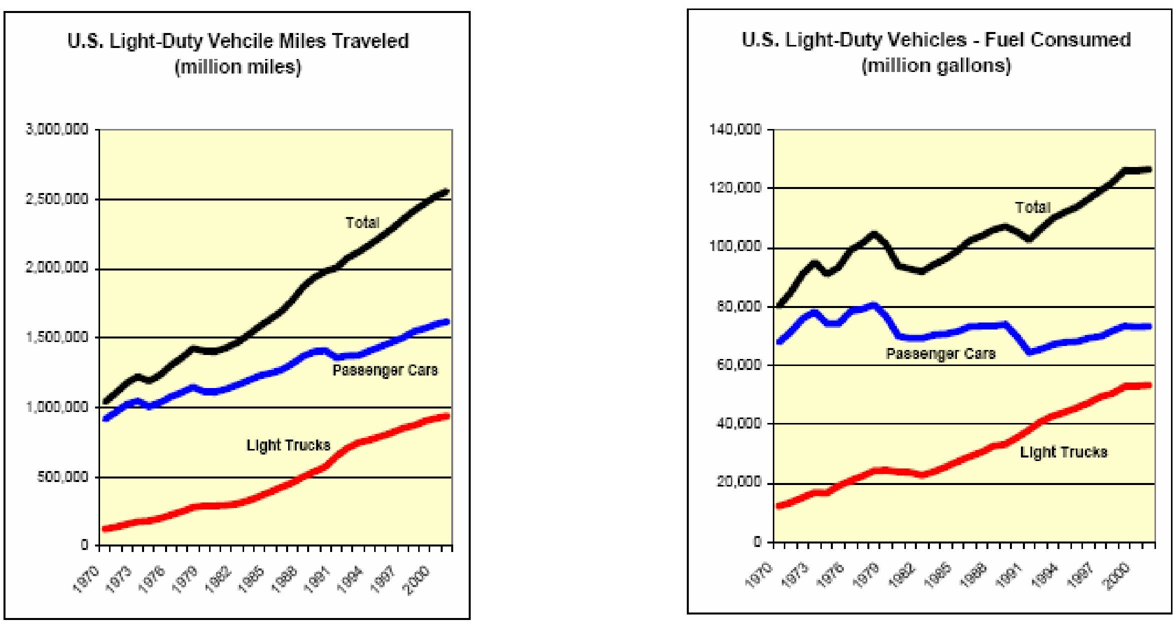
By: Alice Liddell and Sam Krasnow

Over the past 20 years, emissions from the light-duty vehicle sector have increased dramatically despite improvements in engine and drive-train efficiency. This is the result of two factors:

- GHG emissions per mile traveled of the light vehicle fleet has gone up due to the increased use of heavier vehicles, such as light trucks and SUVs, that are less efficient and continue to use gasoline as the primary fuel.
- The number of vehicle miles traveled (VMT) by this fleet has increased substantially due to the rising number of vehicles on the road and the longer distances we travel every year.

In the U.S., total fuel use by passenger cars has increased roughly 17% compared with a 40% increase in fuel use by light trucks. (See Figure 2.11).

Figure 2.11: U.S. Light-Duty Vehicle VMT and Fuel Consumed[1]



Source: Oliver, Pollution Probe, Greenhouse Gas Emission and Vehicle Fuel Efficiency Standards for Canada (2005)

In Canada, while GHG emissions from passenger cars fell by 9% between 1990 and 2001, GHG emissions increased 79% due to the higher number of light-duty trucks on Canadian roads.[2]

[1] Oliver, Bob. 2005 *Greenhouse Gas Emission and Vehicle Fuel Efficiency Standards for Canada*, Pollution Probe, p. 70, http://www.pollutionprobe.org/Reports/vehiclefuel.pdf citing Transportation Energy Data Handbook: Edition 23, Oak Ridge National Laboratory.

[2] Parliament Research Branch Economics Division "Fuel Efficiency of Motor Vehicles in Canada", January 2004 http://dsp-psd.pwgsc.gc.ca/Collection-R/LoPBdP/PRB-e/PRB0348-e.pdf.

In addition to our earlier recommendations to promote the transition to low-carbon and no-carbon energy carriers, three additional recommendations for reducing GHG emissions from light vehicles should be pursued:

- implementing mandatory vehicle emission standards in order to lower GHGs emitted per mile traveled;
- increasing vehicle efficiency standards in order to lower energy consumed per mile;
- reducing vehicle miles traveled.

7.1 Implement Emission Standards for all Light-Duty Vehicles

Summary

In 2005, all New England states except New Hampshire opted into California's LEV II standards, and were joined by New Jersey, New York, Pennsylvania, Oregon and Washington. Subsequently, California enacted the Greenhouse Gas Emissions Standards for Vehicles directing a rulemaking to develop regulations that achieve "the maximum feasible and cost-effective reduction of GHG" from light vehicles sold in the state.

New Hampshire and the five Eastern Canadian provinces should establish individual plans for incorporating the California GHG Emission Standards for Vehicles and move forward implementing those plans. States should make clear to courts and federal agencies their interest in adopting California's standard and the arguments that support EPA granting the necessary Section 209 waiver. Once the GHG Emission Standards for Vehicles comes into effect, officials in the NE-EC region should work with CARB to ensure that GHG emissions regulations are strengthened over time.

States and provinces also should take steps to move cleaner cars into the marketplace. Use of procurement policies to require purchase of the cleanest possible cars (*e.g.,* for state or provincial fleets) and financial incentives such as through "Feebates" should be considered.

Incorporating off-the-shelf technologies into new cars sold under the standards is expected to result in GHG emission reductions of approximately 34% for new cars and light trucks and 25% for new larger trucks and SUVs by 2016. If timely implemented in every jurisdiction in the NE-EC region, the California GHG Emissions Standards for Vehicles would reduce CO_2 emissions from 2000 levels 10.6 $MMTCO_2$ by 2020 (from 83 to 72.4 $MMTCO_2$). Assuming a price of $2.00 per gallon vehicle owners will save between $300 and $2,200 over the life of the vehicle.

Opportunity

Emission Standards

Federal Standards

For all 50 U.S. states, the federal government instituted Tier 1 emissions standards for light-duty vehicles from 1994-2004 and strengthened them with Tier 2 emissions standards, phased in between 2004 and 2009. The aim of these standards is to reduce criteria pollutants, including: carbon monoxide, nitrogen dioxide, ozone, lead, sulfur dioxide or particulate matter. These standards do not regulate CO_2. Regulations came into effect in January 2004 under the Canadian Environmental Protection Act (CEPA) to align Canadian regulations with U.S. Tier 2 emissions standards.

California's Standards

All new vehicles sold in the U.S. are subject to the federal Tier 2 emissions standards, with the exception that, in certain areas of the country, new vehicles may be subject to a more stringent state-based standard created by California. This is made possible through California's special treatment under the Clean Air Act Amendments (CAAA) of 1990, Section 209(a), which enables the state to set more stringent emission standards than the Federal standard. California must obtain a waiver from EPA in order for its standards to be effective. Section 177 of the CAAA allows any state failing to meet the National Ambient Air Quality Standards (NAAQS) for criteria pollutants to adopt California's auto emission standards. Any state deciding to adopt California's auto standards must adopt standards identical to California' standards for each model year.

In 1990, California first created its Low Emission Vehicle (LEV) regulation, which ran from 1994 to 2004 and was slightly more stringent than the federal Tier 1 standards. Maine, Massachusetts, Vermont and New York adopted California's LEV standards in the mid-1990s in lieu of federal standards. At the same time, New Hampshire, Connecticut, and Rhode Island participated in the federal National Low Emission Vehicle Program (NLEV), where auto manufacturers agreed to provide voluntary, nationwide emissions reductions beyond federal Tier 1 regulations on the condition that participating states did not implement California's LEV standards before 2006.

California adopted a second round of emission standards, called LEV II, to be in effect from 2004 to 2010.[3] LEV II standards require that 90% of new cars and light-duty trucks meet stricter tailpipe and evaporative emission standards.

In 2005, Connecticut and Rhode Island joined the other New England states (except New Hampshire) as well as New Jersey, New York, Pennsylvania, Oregon and Washington and opted into California's LEV II standards.[4]

While both California's LEV II standards and the federal Tier 2 standards provide substantial reductions in emissions of criteria pollutants from new vehicles, California's LEV II standards are more stringent. For instance, studies have shown that there will be additional reductions in vehicle hydrocarbon emissions of 4% in 2010 and 16% by 2020 under the LEV II program compared to the federal Tier 2 program.[5] The California LEV II program has two additional components – the Zero Emission Vehicle (ZEV) sales mandate and the Non-Methane Organic Gas (NMOG) rule – that annually increase fleet standards, and thus will force manufacturers to introduce better cars or sell more of their cleaner cars. The ZEV regulation requires that by 2010, 10% of automobiles and light trucks be ZEV, and the standard will increase incrementally to 16% by 2018.[6]

Experts agree that modest GHG emission reductions are likely to occur as a result of implementing LEV II standards in place of Tier 2 standards. Environmental groups project that the GHG reductions from LEV II would be about 2.5% by the year 2020, while experts from the auto industry project it would be closer to 1%.[7]

<u>California's Greenhouse Gas Emission Standards for Vehicles</u>

In 2002, California renewed its effort to reduce GHG emissions from light vehicles when AB 1493, commonly known as the "Pavley law," was enacted. The law directed the California Air Resources Board (CARB) to develop and adopt regulations that achieve "the maximum feasible and cost-effective

---

[3] 13 CA ADC § 1961.
[4] Connecticut: Adopted 12/22/2005. Regulations of Connecticut State Agencies (RCSA), Title 22a § 22a-174-36b(n); Maine: Adopted 12/1/2005. Maine Administrative Code 06-096 Ch. 127; Massachusetts: Adopted 12/30/2005. 310 Code of Massachusetts Rules 7.40. Rhode Island: Adopted 12/22/2005 Rhode Island Department of Environmental Management, Division of Air Resources, Air Pollution Control Regulation No. 37; Vermont: Adopted 11/7/05 Air Pollution Control Regulations, Subchapter XI, Low Emission Vehicles Code of Vermont Rules 5-1103(b).
[5] "Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program" October 2003 Prepared by Northeast States for Coordinated Air Use Management (NESCAUM) Cambridge Systematics, Inc. http://www.nescaum.org/documents/lev_report_final.pdf/view?searchterm=LEV.
[6] 13 CA ADC § 1962.
[7] *See., e.g.,* Northeast States for Coordinated Air Use Management NESCAUM, White Paper "Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program" October 2003; *see also*, Source: Heiken, J., "Greenhouse gas reductions from light-duty vehicles in Connecticut," Memorandum to Alliance of Auto Manufactures, Nov. 17, 2003.

reduction of GHG" from light vehicles sold in California. CARB subsequently developed the Greenhouse Gas Exhaust Emission Standards and Test Procedures - 2009 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles (or GHG Emission Standards for Vehicles) in 2004 that apply to sales of light vehicles in the 2009 model year and beyond. [8] The regulations are be expressed in CO_2 equivalent emissions and incorporated into the state's current LEV II tailpipe emissions program. There is a CO_2e fleet average emission requirement for the passenger car/light-duty truck 1 (PC/LDT1) category and another for the light-duty truck 2 (LDT2) category, just as there are fleet average emission requirements for criteria pollutants for both categories of vehicles in the LEV I and II program.

Table 2.3: CO_2 Equivalent Emission Standards for MY 2009 though 2016[9]

CO_2 Equivalent Emission Standards for Model Years 2009 through 2016			
Tier	Year	CO_2 Equivalent Emission Standard by Vehicle Category g/mile	
		PC/LDT1	LDT2
Near-Term	2009	323	439
	2010	301	420
	2011	267	390
	2012	233	361
Mid-term	2013	227	355
	2014	222	350
	2015	213	341
	2016	205	332

Source: CARB (2004)

The GHG Emission Standards for Vehicles cover four sources of global warming emissions:

- carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N_2O) emissions resulting directly from operation of the vehicle;
- CO_2 emissions resulting from operating the air conditioning system;
- refrigerant emissions from the air conditioning system due to either leakage, losses during recharging, or release from scrappage of the vehicle at end of life;
- upstream emissions associated with the production of the fuel used by the vehicle.[10]

All GHG (including CO_2, methane, nitrous oxides exiting the exhaust system and the emissions from coolants in the air conditioning system) are converted to a CO_2 equivalence (CO_2e).[11]

[8] Title 13, California Code of Regulations, § 1960 and 1961 *et seq.*
[9] CARB ISOR http://www.dec.state.ny.us/website/dar/218risra.html.
[10] "California's Vehicle Global Warming Pollution Reduction Regulation: How it Works," California Clean Cars Program, http://www.calcleancars.org/factsheets/staffproposal.pdf.
[11] For more details *see*: CARB http://www.arb.ca.gov/regact/grnhsgas/isor.pdf .

Applications of off-the-shelf technologies to comply with California's GHG standards are expected to result in GHG emission reductions of approximately 34% for new cars and light trucks and 25% for new larger trucks and SUVs by 2016.[12] Across the entire light vehicle class of vehicles, it is estimated that GHG reductions will be reduced by approximately 30% by 2016.

All states that have opted into the California LEV II program are required to adopt emission standards identical to California standards in order to stay within the terms of Section 177 of the Clean Air Act Amendments. These states need to adopt the GHG emissions reduction standards on the same timeframe as California and are required to give a 2 year lead time to manufacturers before the standards go into effect.

California's GHG Emission Standards for Vehicles have affected Canadian legislation. In response to proposals by Canadian officials to adopt these standards, on April 5, 2005, the Government of Canada and the Canadian automotive industry, representing all major automakers, reached an agreement to reduce GHG emissions from all cars sold in the country.

Under this new Memorandum of Understanding (MOU), the Canadian automotive industry agreed to voluntarily reduce GHG emissions of new light-duty vehicles in Canada so that by 2010, annual emissions reductions will reach 5.3 megatonnes (Mt), which is estimated to be 6% below BAU emissions, with intermediate targets of 2.4 Mt in 2007, 3 Mt in 2008 and 3.9 Mt in 2009. GHG emissions reductions from Canadian cars can come from a variety of areas such as transmission, power-train and engine improvements as well as other vehicle improvements.[13]

Cost of GHG Emission Standards for Vehicles

CARB estimates that costs for the technology needed to meet the GHG Emission Standards for Vehicles standards are expected to average about $325 per vehicle in 2012 and about $1,050 per vehicle to comply in 2016.

The CARB staff analysis concludes that the rule will result in long-term savings for vehicle buyers by lowering operating expenses that will more than offset the added costs of the new vehicles. Table 2.4 shows the estimated costs in more detail.

[12] *For detailed lists of off-the shelf technology and carbon reductions see*, California Environmental Protection Agency Air Resources Board Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles http://www.arb.ca.gov/regact/grnhsgas/isor.pdf, Table 5.2-3: Potential Carbon Dioxide Emissions Reductions from Individual Technologies (from NESCCAF, 2004) p. 59 and Table 5.3-8. Summary of Cost Effectiveness Parameters for Climate Change Emission Reduction Engine, Drivetrain, and Hybrid-Electric Vehicle Technologies p.97

[13] As described in Appendix 3 of the MOU, specific improvements include: Transmission improvements (*e.g.*, continuously variable transmission, 6+ Speed Transmissions, Advanced Overdrive Systems, Electronically Controlled Torque Converters), power-train (*e.g.* high efficiency alternators, hydraulic cooling systems), engine improvements (*e.g.* cylinder deactivization, turbo-charging and supercharging, variable valve timing and lift) and other vehicle improvements (*e.g.* lightweight materials). Memorandum of Understanding between the Government of Canada and the Canadian Automotive Industry Respecting Automobile Greenhouse Gas Emissions April 5, 2005 http://www.nrcan-rncan.gc.ca/media/mous/2005/20050405_e.htm.

Table 2.4: Average Cost of Control by Model Year for the Six Major Automakers[14]

Average Cost of Control by Model Year for the Major Six Automakers			
Year			**All Major 6**
2009		PC/LDT1	$17
		LDT2	$36
2010	Near-Term	PC/LDT1	$58
	Phase in	LDT2	$85
2011		PC/LDT1	$230
		LDT2	$176
2012		PC/LDT1	$367
		LDT2	$277
2013		PC/LDT1	$504
		LDT2	$434
2014	Mid-Term	PC/LDT1	$609
	Phase in	LDT2	$581
2015		PC/LDT1	$836
		LDT2	$804
2016		PC/LDT1	$1,064
		LDT2	$1,029

Source: CARB (2004)

Using the average increase in vehicle prices associated with the fully phased-in regulation (2016), and an assumed fuel price of $1.74 per gallon, CARB calculated that the increased vehicle payment minus the reduction in operating cost would result in a monthly savings of about $3.50 to $7.00 or yearly savings of $42 to $84 dollars. Assuming a price of $2.00 per gallon vehicle owners will save between $300 and $2,200 over the life of the vehicle for a range of CO_2 reductions up to about 45%. At higher fuel prices, the savings increase.

Table 2.5: Payback Time for the Average Passenger Vehicle[15]

		Fuel Price ($/gallon)		
	Technology Cost	$1.74	$2.00	$2.25
		Payback Time (years)		
Near Term	$326	1.6	1.4	1.2
Mid-Term	$1,048	4.3	3.6	3.1

Source: Union of Concerned Scientist, "Consumer Benefits of CA's Vehicle Global Warming Law" (2004)

CARB Developing Rules to Deal with a Variety of Fuels

In an attempt to reflect the varying net GHG emissions from alternative fuels and alternative fuel vehicles, CARB developed an adjustment factor for alternative fuel vehicles to factor in upstream GHG

---

14 Control costs from revised Table 6.2-8, Addendum to CARB ISOR, Sep. 2004. http://www.dec.state.ny.us/website/dar/218risra.html.

15 Union of Concerned Scientists: "Consumer Benefits of CA's Vehicle Global Warming Law" November 2004, http://www.ucsusa.org/clean_vehicles/california_driving/consumer-benefits-of-californias-pavley-law.html.

emissions from fuel production/distribution. As discussed in the previous section on Fuels (Priority 6), new analysis has made clear that the CARB adjustment factors on ethanol are optimistic. For completeness, the CARB adjustment factors are reported in the next two tables, but we reiterate our admonition that some experts dispute the appropriateness of these factors. For example, they do not incorporate significant net GHG increases from land conversion that is likely to result if and when ethanol production is increased to meet rising national and international demand for biofuels.

Table 2.6: Potential Carbon Dioxide Equivalent Emissions Reductions with Alternative Fuel Vehicle Technologies for Passenger Cars[16]

Vehicle type	Vehicle CO2 emissions (g/mi)	Upstream CO2 equivalent emissions (g/mi)	Total CO2 emissions (g/mi)	Lifetime CO2 equivalent emissions (ton)	Lifetime CO2 equivalent emissions reduced from 2002 baseline (ton)	Percent reduction from Conventional Gasoline Vehicle
Conventional vehicles	346.7	102.7	449	99.9	0.0	0%
Compressed natural gas (CNG)	284.8	92.9	378	83.9	15.9	16%
Liquid petroleum gas (LPG)	313.9	50.4	364	80.9	18.9	19%
HEV20	89.0	82.0	171	38.1	61.8	62%
Ethanol (E85)	356.9	-12.7	344	76.5	23.4	23%
Electric	0	150	150	33.4	66.5	67%

CARB has also developed a CO_2 adjustment factor so that all vehicles would be assessed based on both upstream and "direct" emissions at the vehicle. To simplify calculations, when certifying gasoline or diesel-fuel vehicles, manufacturers would report only the "direct" or "vehicle" emissions. For alternative fuel vehicles, however, exhaust CO_2 emissions values will be adjusted to account for the upstream emissions, using emissions from conventional vehicles as a baseline.

Table 2.7: Upstream Adjustment Factor for Alternative Fuel Vehicles[17]

Fuel	Fuel Cycle Emission Ratio (upstream g CO_2/ exhaust g CO_2)	Fuel Cycle Factor (g/g CO_2)	CO_2 Adjustment Factor - ratio to RFG (g/g CO_2)
Fuels with Direct CO_2 Emissions			
Conventional vehicles (RFG)	0.31	1.31	1.00
Compressed natural gas (CNG)	0.35	1.35	1.03
Liquid propane gas (LPG)	0.17	1.17	0.89
E85, corn	-0.04	0.96	0.74
Fuels with No Direct CO_2 Emissions [2]			
Electricity	n/a	n/a	115 g/mi
Hydrogen –ICE[3]	n/a	n/a	290 g/mi
Hydrogen – Fuel cell[3]	n/a	n/a	210 g/mi

1 Emission estimates from TIAX, LLC.
2 Emission estimates have been reduced by 31 percent to be consistent with the Adjustment Factors for vehicles with direct emissions.
3 Assumes a fuel usage of 32 miles per kilogram for an internal combustion engine vehicle and 45 miles per kilogram for a fuel cell vehicle (DOE Fuel Economy Guide). Hydrogen produced by on-site steam reformation which is consistent with the goals set forth by the California Hydrogen Economy Blueprint Plan for the 2009 timeframe. Hydrogen production emission estimate from TIAX, LLC.

---

[16] TIAX, LLC, Climate Change Friendly Alternative Fuel Vehicle Analysis; EPRI report Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options http://www.arb.ca.gov/regact/grnhsgas/isor.pdf Table 5.2-13.
[17] Assumes that 31% of emissions from conventional vehicles are upstream emissions.

Potential Emissions Reductions

Looking only at the New England states that have already adopted California's family of emission standards (GHG Emission Standards for Vehicles, LEV II and ZEV) CO_2 emissions are projected to drop 10.3 $MMTCO_2$ from current levels by 2020 (*i.e.*, from 55.9 to 45.6 $MMTCO_2$).

Extrapolating from this, and using NESCAUM's assumption that California's emissions standards will reduce CO_2 emissions from light-duty vehicles by 18% by 2020, we estimate that the NE-EC region as a whole could reduce emissions by 16.1 $MMTCO_2$ from Business as Usual emissions projections of 88.6 $MMTCO_2$.

Table 2.8: Estimated Light-Duty Vehicle Emissions due to GHG Standards in 2020 (Million Metric Tons CO_2)[18]

State	Projected BAU Emissions in 2020	Projected Emissions in 2020	Reduction in Emissions by 2020	Percent Reduction
Connecticut	15.1	12.2	2.8	19%
Maine	7.4	6.1	1.3	18%
Massachusetts	25.2	20.5	4.6	18%
New Hampshire	NA	NA	NA	NA
Rhode Island	4.4	3.6	0.8	18%
Vermont	3.8	3.2	0.7	18%
Newfoundland	1.4	1.1	0.3	18%
Prince Edward Island	0.68	0.6	0.1	18%
Nova Scotia	3.5	2.9	0.6	18%
New Brunswick	2.9	2.4	0.5	18%
Quebec	24.2	19.8	4.4	18%
Total in $MMTCO_2e$	**88.6**	**72.4**	**16.1**	**18%**

Source: NESCAUM for New England and ENE Projection for Eastern Canada

Environment Northeast

Looking another 10 years out into time to 2030, and using NESCAUM's assumption that California's standards will reduce emissions in the New England states by 24%, the NE-EC region could reduce emissions by 24.6 $MMTCO_2$. These projections assume that by 2020 there is a significant market penetration of cars meeting California's standards and by 2030 most cars and trucks on the road will be compliant with California's standards.

CARB estimates that with other states and Canada adopting the GHG Emission Standards for Vehicles, 76% of vehicles in the passenger and LDT1 class, and 86% of LDT2 class sold in North America will have incorporated technologies to lower emissions by 2012.

Implementation

Adopting California's Emission Standards

Five of the six New England states have opted into the California LEV II program and are in various stages of promulgating rules to implement the CO_2 standards embodied in the Clean Cars program. In these states, the CO_2 emission standards should apply to new light vehicles sold beginning in 2009.

[18] New England Data is from NESCAUM Northeast State GHG Emission Reduction Potential from Adoption of the California Motor Vehicle GHG Standards Summary of NESCAUM Analysis October, 2005. http://bronze.nescaum.org/committees/mobile/summary051018ghg.pdf. Eastern Canadian Data is calculated from provincial GHG inventories compiled by ENE extrapolating the 18% reductions projected for New England Data.

To put this best practice to work for the region, New Hampshire and the five Eastern Canadian provinces should establish individual plans for incorporating the California emission standards and move forward implementing those plans. The Provincial Government of Quebec recently issued its 2006-2015 Energy Strategy which said that the government will promote improvements to the passenger car fleet by changing the standards governing vehicles sold in Quebec to make them more stringent with respect to energy consumption (suggesting they could adopt California standards).[19] Other provinces in the region should follow Quebec's lead in adopting California's standards, making them mandatory instead of simply voluntary as laid out in the MOU.

Shoring up California's GHG Emission Standards for Vehicles

While EPA has granted a Section 209 waiver for California's LEV II standards, such a waiver for the GHG Emission Standards for Vehicles has not yet been granted. At the time of this writing it is unclear if EPA will grant the waiver.

Several lawsuits have also been filed to stop California and other states from adopting regulations that set standards for GHG emissions. In 2005, the Alliance of Automobile Manufacturers and the Association of International Automobile Manufacturers were parties to federal and state lawsuits, contending that California lacks the authority to set standards for GHG emissions since they are not deemed "air pollutants" under the Clean Air Act.[20,21] The auto manufacturers also argue that California's standards constitute de facto fuel economy regulation, which is preempted by CAFE and is therefore prohibited by exclusive federal jurisdiction over fuel efficiency standards. There are also lawsuits in Rhode Island and Vermont where the auto manufacturers have alleged that California does not have the authority to regulate light vehicles in this way and, by extension, neither do other states.[22] In October 2006, the Supreme Court will consider whether the Bush administration must regulate CO_2 to combat global warming, which could also jeopardize plans by California and 10 other states, including most of the Northeast, to require reductions in CO_2 emissions from motor vehicles.[23] If legal challenges to states' authority to regulate CO_2 from light vehicles are successful, alternative measures will need to be considered.

States (and provinces) could pursue opportunities in legal proceedings to make clear their interest in adopting California's Pavley standard and to make clear to EPA, the White House and Congress that EPA should grant a Section 209 waiver to California. On March 30, 2006, 21 senators sent a letter to EPA Administrator Stephen L. Johnson requesting EPA to issue the waiver.[24] CARB and California Governor Schwarzenegger have also written to EPA to request the waiver. Other states interested in advancing CO_2 emission standards in new cars could muster similar expressions of support from elected officials and constituents and have an important impact on the response from Washington.

---

[19] Natural Resources of Quebec: "Using Energy to Build the Quebec of Tomorrow: Quebec Energy Strategy 2006-2015" energy-strategy-2006-2015-summary.pdf.

[20] Alliance of Automobile Manufactures includes BMW Group, DaimlerChrysler, Ford Motor Company, General Motors, Mazda, Mitsubishi Motors, Porsche, Toyota and Volkswagen.

[21]Association of International Automobile Manufactures includes Honda, Hyundai, Isuzu, Kia, Mitsubishi, Nissan, Peugeot, Renault, Subaru, Suzuki, Toyota.

[22] CA: Central Valley Chrysler-Jeep, Inc. v. Witherspoon, No. 1:04-cv-06663-REC-LJO (E.D. Calif. filed Dec. 7, 2004). VT: Green Mountain Chrysler-Plymouth-Dodge-Jeep v. Torti, No. 2:05-cv-00302-wks (D. Vt. Memorandum Opinion and Order dated May 3, 2006). RI: Association of International Automobile Manufacturers v. W. Michael Sullivan, in his official capacity only as Director of the Rhode Island Department of Environmental Management C.A. No. 06-69T. Maine: February 2006: Court Rejects Carmakers' Challenge to Maine's Clean Car Rule: Case Dismissed on Procedural Grounds . Conservation Law Foundation http://www.clf.org/general/internal.asp?id=820 and http://www.clf.org/programs/cases.asp?id=650.

[23]Massachusetts v. Environmental Protection Agency, No. 05-1120.
http://www.supremecourtus.gov/orders/06grantednotedlist.pdf
Hebert, H. Josef. 2006. High Court mulls greenhouse gas regulation. AP 26 June.

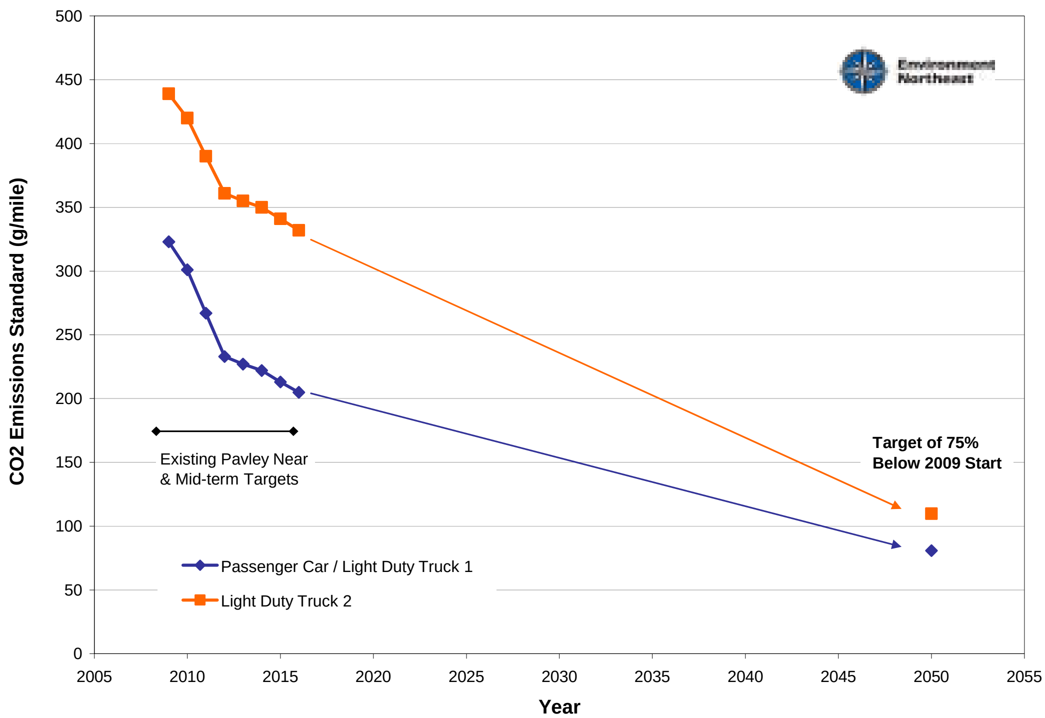
[24] Senators signing the letter represent CT, VT, MA, ME, NH, CA, WA, OR, NJ, NY, PA, MD, NM and AZ.

Next Stage California's Standards

If the California standards are upheld in court, GHG emission reductions could be increased in the future and expanded beyond 2016. Unlike Federal Tier 2 standards, which will remain the same for at least a decade, California's standards will probably continue to become more stringent as the state advances into new phases of the LEV II and Pavley program. As a result, the emissions differences between California and the federal government will likely become even greater.

Once the GHG Emission Standards for Vehicles comes into effect, officials in the NE-EC region should work with CARB to ensure that GHG emissions regulations are strengthened over time. With VMT estimated to increase by 1.8% per year for the light-duty vehicle sector, GHG emissions will continue to increase from this sector even with GHG emissions per vehicle decreasing. As a result, in order to meet the region's GHG emission goals, it is plausible that GHG targets could be ratcheted down over time, ultimately reducing emissions by 75% by 2050 as shown in Figure 2.12.

Figure 2.12: Emissions Trajectory from Existing GHG Standards and Potential Target for 2050



Continued technical innovation and switching to alternative sources of fuel, as discussed in other sections of this report, will be necessary to reach these goals.

Adopt the California emission standard at the federal level

The states that have adopted California's standards have shown leadership in reducing GHG emissions. Eventually, the federal government should follow the states' lead and set limits on GHG emissions from light-duty vehicles. Several organizations have started suggesting ways in which CAFE can be modified in this direction. For instance, the Pew Center on Global Climate Change has recommended that the CAFE program be converted from a miles per gallon (MPG) based standard into a strengthened, tradable corporate average CO_2 (or GHG) emissions standard.[25] We recommend that the federal government keep efficiency standards like CAFE, but also add emissions standards. This could be accomplished by having a federal emission standard that takes into account net GHG emissions per

[25] The Pew Center on Global Climate Change: Agenda For Climate Action February 2006 http://www.pewclimate.org/docUploads/PCC%5FAgenda%5F2%2E08%2Epdf.

joule of energy. This type of standard would ensure that light-duty vehicles are the least polluting while producing maximum energy output per mile. As a result, this would help encourage the development of fuels and infrastructure by supporting biofuels, hydrogen, and other low GHG fuel alternatives. An emissions standard without an efficiency standard risks encouraging vehicles that emit no CO_2 on-board yet make inefficient use of this energy (due to weight or other energy consuming systems). Similar to the GHG Emission Standards for Vehicles, federal emissions standards should move toward accounting for upstream emissions associated with fuels to ensure that all fuels compete, from a climate standpoint, on a level playing field.

Moving Cleaner Cars into the Marketplace

Promoting the sale and purchase of cleaner cars in the marketplace helps increase economies of scale in the manufacture and distribution of these models, which in turn makes these models more readily available and affordable to consumers.

Promotion of cleaner cars can be advanced though a variety of measures. One common tactic is establishing procurement policies for vehicles that are purchased, leased or rented with public funds. Since there generally a 25% difference in the GHG emission rate between the most and least polluting vehicles in each vehicle class (*e.g.*, sedan, station wagon, pickup truck, van, etc.) states and provinces can help lower their operating costs while at the same time moving cleaner cars into the marketplace by requiring the purchase, lease or renting of the lowest emitting vehicles in each class. A similar approach is to offer a variety of financial incentives and initiatives and develop similar purchasing programs to encourage private vehicle fleets to purchase lower emitting vehicles.

States and provinces should consider offering financial incentives to increase the market penetration of these lower emitting vehicles. For example, tax breaks or rebates may be given to individuals who purchase hybrid vehicles. In Connecticut, hybrid vehicles getting at least 40 mpg are exempt from the states 6% sales tax. In Maine, hybrid owners have been eligible for a partial sales tax credit of $300-$500.[26] PEI is the only eastern province so far to provide a rebate for hybrid vehicles, and it currently reaches as high as $3000.[27] The government of Quebec's new Energy Strategy plans to reimburse the QST (maximum $1,000) for new hybrid vehicles (2006-2007 Budget). Quebec's government is also examining the possibility of creating more financial incentives for purchasing fuel-efficient vehicles.[28]

The idea of a graduated schedule of taxes and rebates, or "Feebates," has been suggested in the New England Governors and Eastern Canadian Premiers Climate Action Plan as well as in the climate action plans of CT, ME, RI and MA as a way to reach CO_2 reduction targets from the transportation sector. A Feebate program uses both incentive "rebates" to encourage consumers to purchase relatively low emitting CO_2 vehicles and disincentives "taxes" to discourage consumers from buying relatively high-emitting CO_2 vehicles. [29] A Feebate program can be designed in several different ways, taking into account the classes of vehicle to be covered, the manner in which the fees and rebates are to be calculated, and the way in which those fees or rebates are to be collected. In addition, a Feebate program can be designed to either generate net revenue or to be revenue neutral (*i.e.*, rebates disbursed equal the amount of fees collected, less administrative costs).[30] While Connecticut, Maine and Massachusetts have proposed Feebates at various times, they have struggled to generate political support and have not yet been successful.[31]

---

[26] MRSA 36 Sections 1752 and 1760-79, http://go.ucsusa.org/hybridcenter/incentives.cfm#ME.
[27] http://www.kanetix.ca/ic_auto_info_auto_articles_48.
[28] Natural Resources of Quebec: "Using Energy to Build the Quebec of Tomorrow: Quebec Energy Strategy 2006-2015" energy-strategy-2006-2015-summary.pdf.
[29] *See, generally, Connecticut Clean Cars Alliance 2006 Legislative Report: The Clean Car Incentives Program*, Charles J. Rothenberger, Connecticut Fund for the Environment and Eric Haxthausen.
[30] Connecticut Clean Cars Alliance 2006 Legislative Report: The Clean Car Incentives Program Charles J. Rothenberger, Connecticut Fund for the Environment and Eric Haxthausen.
[31] *See*, *e.g.*, http://www.clf.org/programs/projects.asp?id=570.

7.2 Improve Fuel Economy Standards in the U.S. and Canada

Summary

We recommend that states and provinces actively work to support more stringent federal fuel economy standards and to have Canada make its standards mandatory and enforceable. It would improve the Corporate Average Fuel Economy (CAFÉ) and Company Average Fuel Consumption (CAFC) framework if the standards were converted to joules per mile rather than miles per gallon. As we transition away from an economy in which motor gasoline and diesel fuels are the exclusive energy supply for vehicles, switching the measure of efficiency to joules per mile would better enable the system to reflect the different energy content of competing fuels or energy carriers and the differing vehicles they use.

In March 2006, National Highway Traffic Safety Administration (NHTSA) reformed the way in which CAFE standards will be computed for light trucks and increased the MPG requirement. By 2011, every manufacturer's required level of CAFE will be based on target levels set according to vehicle size—instead of having average mpg fleet requirements—each vehicle mpg standard will be based on a vehicle's footprint.

In addition, new CAFE standards were issued for light trucks that will lead to a fleet-wide average of 24 mpg by 2011 and increase the vehicle weight exemption to 10,000 lbs up from 8,500 lbs. The program will be phased in through 2010 (22.5 mpg for MY 2008, 23.1 mpg for MY 2009, and 23.5 mpg for MY 2010), with automakers having the option of complying under the old system or using the new CAFE standards based on a vehicle's footprint.

Canada has set Company Average Fuel Consumption (CAFC) targets to the same fuel efficiency required by the U.S. CAFE standards. The major difference between CAFC and its U.S. counterpart is that the CAFC targets are voluntary.

One of the barriers to improved fuel efficiency in the NE-EC region is the reality that it has been politically difficult to pass significant changes to CAFE in the federal policy forums. In addition, federal law preempts independent fuel efficiency regulation by state and municipal governments. The CAFC targets in Canada are pegged to the CAFE standards, although Canada has not yet revised the CAFC targets to match the newest CAFE standards for light trucks.

The Carbon Mitigation Initiative has calculated that globally, the transportation sector could reduce emissions by about 1 billion tons per year by doubling the efficiency of all the world's cars from 30 to 60 mpg.

Opportunity

In response to the oil embargo of 1973-1974, Congress passed the Energy Policy and Conservation Act in 1975 which added Title V, "Improving Automotive Efficiency," to the Motor Vehicle Information and Cost Savings Act and established CAFE standards for passenger cars and light trucks.[32]

The CAFE standards required the fuel efficiency average of 1985 model year fleet of passenger cars to be at least 27.5 mpg, double the 1974 level of 13.6 mpg.[33] The NHTSA briefly relaxed the standard for model years 1986-1988 and then brought it back up to 26.5 mpg and 27.5 mpg, respectively, for the 1989 and 1990 model years.[34] Since 1990, NHSTA has not sought Congressional approval for increases beyond 27.5 mpg and thus the U.S. CAFE standard for passenger cars has remained stagnant.[35]

For light trucks, CAFE standards remained between 20.0-20.5 mpg for the majority of the late 1980s and 1990s. On March 31, 2003, NHTSA issued new light truck standards, setting a standard of 21.0 mpg for MY 2005, 21.6 mpg for MY 2006, and 22.2 mpg for MY 2007.[36] Given CAFE's limited application to vehicles weighing less than 8,500 pounds, many heavier pick-up trucks, vans and SUVs sold in the light

[32] National Highway Traffic Safety Administration http://www.nhtsa.dot.gov/cars/rules/cafe/overview.htm.
[33] Oliver, p. 31.
[34] *Ibid.*, p. 36.
[35] *Ibid.*
[36] 49 CFR Part 533 Light Truck Average Fuel Economy Standards.
Model Years 2005-2007.

vehicle class have not been impacted by the fuel efficiency regulatory regime.[37] In March 2006, NHTSA reformed the way in which CAFE standards will be computed for light trucks and increased the MPG requirement. By 2011, every manufacturer's required level of CAFE will be based on target levels set according to vehicle size—instead of having average mpg fleet requirements—each vehicle mpg standard will be based on a vehicle's footprint.

In addition, new CAFE standards were issued for light trucks that will lead to a fleet-wide average of 24 mpg by 2011 and increase the vehicle weight exemption to 10,000 lbs up from 8,500 lbs.[38] The program will be phased in through 2010 (22.5 mpg for MY 2008, 23.1 mpg for MY 2009 and 23.5 mpg for MY 2010), with automakers having the option of complying under the old system or using the new CAFE standards based on a vehicle's footprint.

The Canadian Government established the Joint Government-Industry Voluntary Fuel Consumption Program at the same time the U.S. was originally enacting CAFE, and the following year calibrated the targets – called Company Average Fuel Consumption (CAFC) targets – to the same fuel efficiency required by the U.S. CAFE standards.[39] The major difference between CAFC and its U.S. counterpart is that the CAFC targets are voluntary.[40] Table 2.9 summarizes the CAFC voluntary targets for passenger cars and light trucks.

Table 2.9: Canada CAFC Standards[41]

	CAFC Standard	Model Year
Passenger Car	8.6 L / 100 km	1990 – present
Light Truck	11.4 L / 100 km	1996 – 2004
	11.2 L / 100 km	2005
	10.9 L / 100 km	2006
	10.6 L / 100 km	2007

Source: Oliver, Pollution Probe, *Greenhouse Gas Emission and Vehicle Fuel Efficiency Standards for Canada* (2005)

Canada has not yet revised the CAFC targets to match the newest CAFE standards for light trucks.

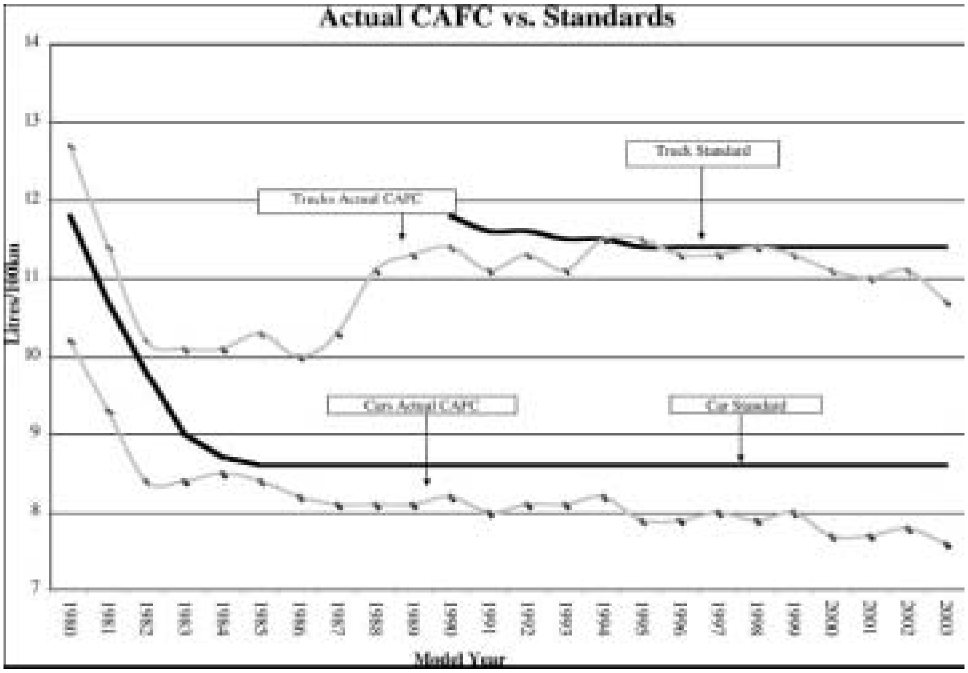
In 1982, Parliament passed the Motor Vehicle Fuel Consumption Standards Act, granting the ministers of Transport Canada and Natural Resources Canada the power to recommend legally binding standards on auto manufacturers. However, the Act was never proclaimed, because the Minister instead accepted the vehicle manufacturers' voluntary commitment to meet the required standards.

The Act remains as contingency legislation and could be implemented in the future if, for example, auto companies fail to meet the fuel efficiency goals voluntarily or if other developments justify a mandatory program.[42] Figure 2.13 indicates the correlation between the CAFC targets and actual fuel consumption among light vehicles sold in Canada and shows that, through 2003, most companies were meeting the CAFC targets.

---

[37] Findings from a 2002 study prepared for the Department of Energy by the Oak Ridge National Laboratory. http://www.nhtsa.gov.
[38] http://nhtsa.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/2006FinalRule.pdf.
[39] Oliver, p. 41.
[40] *Ibid.*
[41] *Ibid.*
[42] Canada's Fuel Economy Standards http://strategis.ic.gc.ca/epic/internet/inauto-auto.nsf/en/am01206e.html.

Figure 2.13: Actual Corporate Average Fuel Consumption vs. Standards in Canada[43]



Source: Natural Resources Canada, in Feng and Sauer, *Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards around the World* (2004**)**

One of the barriers to improved fuel efficiency in the NE-EC region is the reality that it has been politically difficult to pass significant changes to CAFE in the federal policy forums. In addition, federal law preempts independent fuel efficiency regulation by state and municipal governments. The express language of the United States Code makes clear the limitations against states regulating fuel economy standards for automobiles:

> When an average fuel economy standard prescribed under this chapter is in effect, a State or a political subdivision of a State may not adopt or enforce a law or regulation related to fuel economy standards or average fuel economy standards for automobiles covered by an average fuel economy standard under this chapter.[44]

This barrier has a similar impact on Canadian provinces, because the CAFC targets are pegged to the CAFE standards.

Implementation

The recent change to U.S. CAFE standards for light-duty trucks is a first step toward improving fuel efficiency regulation in North America. To ensure more significant GHG reductions through better fuel efficiency, however, states should press the federal government to significantly raise the CAFE standards for light trucks and cars.

---

[43] Feng and Sauer, *Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards around The World*, prepared for Pew Center on Global Climate Change, 2004, p. 10, citing Natural Resources Canada, with the following note: "The two solid lines represent CAFC standards for cars and light trucks, respectively. The two gray lines represent fleet-average fuel consumption levels achieved separately by cars and light trucks. When achieved fuel consumption levels are lower than the standards, it indicates that companies are able to meet the standards; otherwise, they would be subject to financial penalties."

[44] US Code Title 49—Transportation, Subtitle VI—Motor Vehicle and Driver Programs, Part C—Information, Standards and Requirements, Chapter 329—Automobile Fuel Economy, § 32919.

For instance, in response to the minimal (1.8 mpg average) increase to the CAFE standards for light trucks by 2011, on May 2, 2006, 10 states (California, Connecticut, Maine, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island and Vermont) sued the federal government to try to force the Bush administration to strengthen gas mileage requirements for sport utility vehicles and pickup trucks. The lawsuit also contends that the NHTFA "failed to conduct a thorough analysis of the environmental benefits of fuel economy regulations and the impact of gasoline consumption on climate change."[45] The Bush Administration asked Congress in late 2006 to give the Transportation Department the authority to reorganize CAFE standards for cars based on a sized-based system similar to light-duty trucks, however, without significant fuel economy increases for both cars and light trucks, emissions will continue to increase. For this reason, states should continue to lead the charge to significantly increase CAFE standards for both cars and light trucks and to see that CAFE is continually revised. Even if mileage standards are increased by 5% every five years for cars, by 2050 the average would only be 42.6 mpg. Led by Princeton University, the Carbon Mitigation Initiative has identified stabilization wedges (1 wedge equals 1 billion tons of carbon per year) and showed that global emissions must be trimmed by roughly 7 billion tons per year (7 wedges) to keep emissions flat for the next 50 years. The Initiative has calculated that the transportation sector could reduce emissions by 1 wedge by doubling the efficiency of all the world's cars from 30 to 60 mpg.[46]

As discussed previously, it would improve the CAFE framework if the standards were converted to joules per mile rather than miles per gallon. As we transition away from an economy in which motor gasoline and diesel fuels are the exclusive energy supply for vehicles, switching the measure of efficiency to joules per mile would better enable the system to reflect the different energy content of competing fuels or energy carriers.

In Canada, provinces should work with federal government to quickly update the CAFC targets and push for these targets to be made mandatory and enforceable in case companies are not able to meet the CAFC targets in the future.

[45]http://www.boston.com/news/local/maine/articles/2006/05/02/maine_among_10_states_suing_over_light_truck_fuel_economy_rules/.
[46] Princeton University: The Stabilization Triangle: Tackling the Carbon and Climate Problem With Today's Technologies
http://www.princeton.edu/~cmi/resources/CMI_Resources_new_files/Wedges_Concept_Game_Materials_2005.pdf.

7.3 Reduce Vehicle Miles Traveled (VMT)

Summary

States and provinces should develop broad and forward-thinking land use and transportation plans in order to stabilize growth in VMT.

Land use and transportation policies are integrally related and should be aligned to achieve the same goals of minimizing our dependence on automobile travel, reducing development pressure on remaining open spaces, and revitalizing urban areas. By requiring alternative scenario analyses for Transportation Improvement Plans (TIPs) and Long Range Transportation Plans (LRTPs), many factors that influence development and infrastructure policy decisions can be identified and relevant impacts can be quantified.

Over the longer term, states and provinces should direct investments in transportation and other infrastructure toward designated growth areas near existing population centers or designated high-growth areas.

Sprawl is the largest influence on VMT per capita, and most vehicle miles are used for commuting and for running errands. Proper regional planning can reduce the need for vehicle use. One goal of "smart growth" policies is to make areas of development more compact. This can be achieved by encouraging "infill" development and redevelopment in existing urban and suburban areas through transfers of development rights, brownfield redevelopment incentives, and urban development programs.

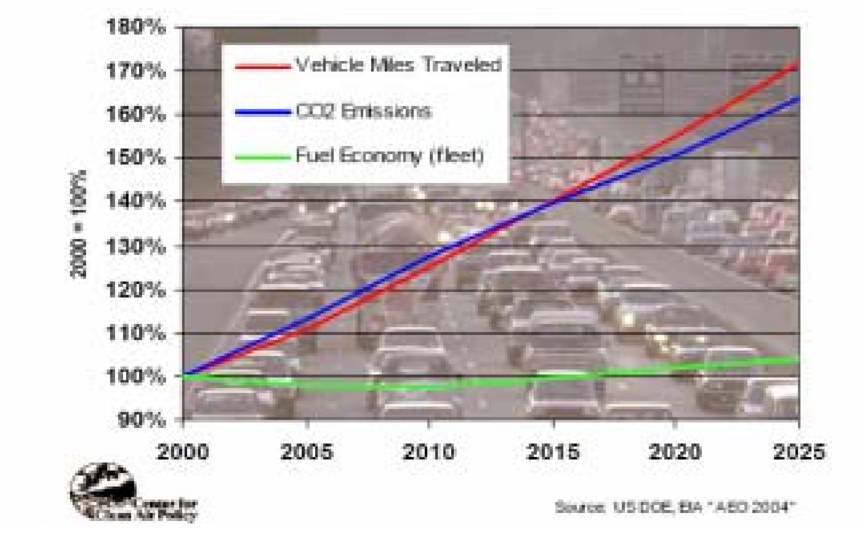
Between 2000 and 2003, VMT increased in the NE-EC region by 1.79%. If it continues to grow at this rate, annual VMT for the NE-EC region is projected to increase from 177,000 million to 400,000 million miles by 2050.

Studies have documented that doubling the residential density of a given neighborhood reduces per-capita VMT by approximately 20 to 38%.

Opportunity

Reducing VMT to meet potential mobility demand is an important tool for reducing carbon and other GHG emissions from the transportation sector. Since all vehicles (with the exception of electric and hydrogen vehicles) will have some degree of carbon emissions, the continued steady growth of VMT will ultimately undercut the reductions in GHG emissions that are achieved through improved fuel economy and lower tailpipe emissions.

Figure 2.14: VMT Has Increased Even as CO_2 Emissions per Vehicles Decreased [47]



[47] Center for Clean Air Policy: CCAP Transportation Emissions Guidebook: Part One: Land Use, Transit & Travel Demand Management written and developed by: Greg Dierkers, Erin Silsbe, Shayna Stott, Steve Winkelman & Mac Wubben, p. 6.

Thus, while we must continue to make progress on vehicle technologies and fuels – and policies to implement them – we must also assess the extent to which we can mitigate growth in VMT. As shown in Table 2.10, between 2000 and 2003, VMT increased in the NE-EC region by 1.79%.

Table 2.10: VMT for Light-duty Vehicles in the NE-EC Region 2000-2003

State/Province	2000	2003	Yearly % Change
Newfoundland and Labrador	2,983.51	2,183.19	-8.94%
Prince Edward Island	734.09	797.41	2.88%
Nova Scotia	5,298.24	6,184.63	5.58%
New Brunswick	5,071.51	4,781.64	-1.91%
Quebec	39,081.69	42,874.29	3.23%
Total ECP Region	53,169.04	56,821.15	2.29%
Connecticut	27,847.45	29,427.82	1.89%
Massachusetts	49,533.22	50,595.84	0.72%
Maine	12,746.22	13,490.98	1.95%
New Hampshire	11,339.76	12,234.81	2.63%
Rhode Island	7,382.12	7,590.09	0.94%
Vermont	6,595.78	7,526.83	4.71%
Total NEG Region	115,444.56	120,866.37	1.57%
Total	**168,613.60**	**177,687.52**	**1.79%**

Source: US Highway Performance Monitoring System and Statistics Canada

Environment Northeast

These results are consistent with the national average growth in VMT of 1.8% per year for the light vehicle sector. If it continues to grow at this rate, VMT for the NE-EC region is projected to increase from 177,000 to 400,000 million by 2050.

Increases in VMT and number of cars on the road have also amplified the amount of traffic congestion, which is not only costly to the economy but also exacerbates the air pollution problem. Table 2.11 shows the excess fuel consumed and the related excess cost caused by congestion in New England's metropolitan areas.

Table 2.11: Components of the Congestion Problem, 2003 Data[48]

Urban Area	Total Travel Delay (1000 hrs)	Total Excess Fuel Consumed (1000 gallons)	Total Excess CO2 Emissions (assuming 20 lbs/gallon) (MMTCO2)	Total Congestion Cost ($ million)	Annual Delay Per Traveler (hours)
Boston, MA-NH-RI	100,237	59,556	0.54	1,692	51
Providence, RI-MA	21,668	10,725	0.10	363	33
Bridgeport-Stamford, CT	14,550	11,032	0.10	250	32
Hartford, CT	7,434	4,923	0.04	127	16
New Haven, CT	5,848	3,940	0.04	100	20
Springfield, MA-CT	2,619	1,526	0.01	44	7

48 Information selected from http://www.csgeast.org/page.asp?id=weeklynewsbulletin67 http://mobility.tamu.edu/ums/congestion_data/tables/national/table_4.pdf and http://mobility.tamu.edu/ums/congestion_data/tables/national/table_2.pdf.

Reducing VMT is an official goal of U.S. government policy and can be found in sections of the Clean Air Act (CAA), the President's 1993 Climate Change Action Plan (CCAP), and the Congestion Mitigation Air Quality Improvement Program (CMAQ). In addition, VMT goal reductions are included in the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21).[49] The Government of Canada has also evaluated ways to reduce emissions from the transportation sector and Transport Canada published *Transportation and Climate Change: Options for Action* in 1999, which summarizes Canadian government sponsored research evaluating transportation emission reduction options including reducing VMT.[50]

Several mechanisms have been developed for transportation planning to reduce VMT and slow the growth in the number of vehicles on the road, as discussed below.

Smart Growth/Urban Planning

Since the degree of sprawl is the largest influence on VMT per capita, and most vehicle miles are used for commuting and for running errands, proper regional planning can reduce the need for vehicle use. One goal of "smart growth" policies is to make areas of development more compact.[51] This can be achieved by encouraging "infill" development and redevelopment in existing urban and suburban areas through transfers of development rights, brownfield redevelopment incentives, and urban development programs. Smart growth strategies emphasize urban sustainability by promoting: concentrated activity centers, mixed use development, increased density near transit, pedestrian oriented design, interconnected travel networks, parking management and open space preservation.[52] By locating new developments close to where a variety of transportation modes can be made available, smart growth initiatives can help reduce VMT. Various urban and suburban area studies have calculated that a doubling of residential density correlates with 20-30% lower per-capita VMT.[53] For example, one study found that households located in the most interconnected areas of Seattle and Atlanta generated less than half the VMT of households located in the least connected areas.[54] Smart growth balances the needs across urban areas to enable residents to meet employment, housing, transportation, recreational, education and commercial needs while minimizing the need to drive.[55]

Mass Transit Systems

Mass transit systems are the ideal transportation mode for urban areas. Mass transit includes bus, rail and water-based transportation systems.

Alternative Transportation

One way to reduce VMT is to increase access to a variety of alternative modes of transportation options in all communities, including land and water based public transit, bicycling, and walking. Bike

---

[49] *For specific language see* CAA Section 182 (c) (5), CAA Section 182 (d) (1), CAA Section 187 (a) (2) (A), CAA Section 187 (b) (2), CCAP-Transportation Actions--page 18, Department of Transportation, Congestion Mitigation and Air Quality Improvement Program, U.S. Code, Title 23, Chapter 1, Section 149. Transportation Equity Act for the 21st Century (TEA-21) , U.S.C. 23, Section 149.

[50]http://www.tc.gc.ca/programs/environment/climatechange/english/climatechange/ttable/Presentation/National_Consultations_(English_color).ppt#259,2,Outline.

[51] Ewing, Reid; Pendall, Rolf; Chen, Don "Measuring Sprawl and Its Impact" Smart Growth America 2002 as referenced in Clean Air & Smart Growth Forum: Recommendations & Next Steps by Steve Winkelman, Manager of Transportation Center for Clean Air Policy July 27, 2005 www.ccap.org/pdf/ Winkelman%20PPT%20for%20CAAAC%20(7-27-05).pdf.

[52] Center for Clean Air Policy: CCAP Transportation Emissions Guidebook, p. 7.

[53] Using Residential Patterns and Transit To Decrease Auto Dependence and Costs by John Holtzclaw, June 1994, Natural Resources Defense Council http://www.smartgrowth.org/library/cheers.html

[54] Frank, 1999, 2000 as referenced in Clean Air & Smart Growth Forum: Recommendations & Next Steps.

55 Center for Clean Air Policy: CCAP Transportation Emissions Guidebook, p. 7.

paths/lanes and pedestrian paths are essential components to encourage alternative transportation and improve the safety and appeal of walking and biking.

Telecommuting

Telecommuting—working outside the traditional workplace, often from home—is a way to reduce a commute altogether. Other alternatives to home offices include telework centers or satellite offices.

"Smart" Transportation Technologies[56]

Technology can also be useful in reducing congestion and thus reducing unnecessary emissions. "Smart" transportation embodies a range of advanced technologies to help smooth traffic flow and increase efficiency of the existing roads. They include: transponders for automated payment of tolls and sensors and control technologies to automate traffic control.

Pay as You Drive (Mileage Based) Insurance

Mileage based insurance rewards those who drive less. This approach raises equity issues with low-income and rural drivers, and many insurers remain resistant to the administrative changes that would be needed to implement mileage-based insurance. Nonetheless, the concept is beginning to make inroads. The Progressive auto insurance company offered a pilot pay as you drive insurance system in Texas, and other pilot programs are underway elsewhere. In 2003, the Oregon Legislature adopted legislation to provide a $100 per policy tax credit to insurers who offer mileage based insurance options.[57]

Congestion Pricing

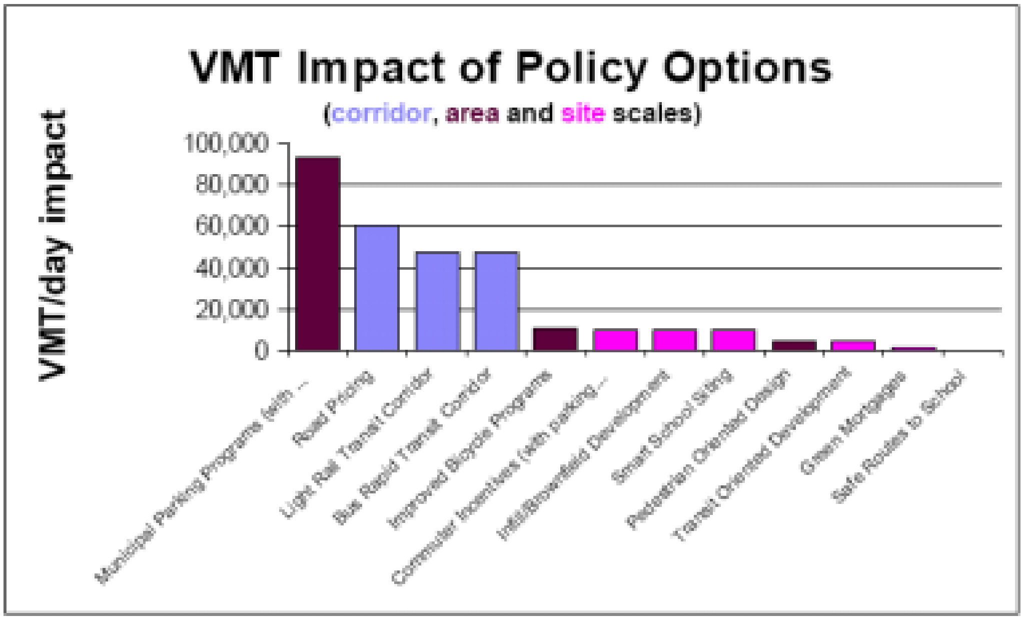
Congestion pricing (also called value pricing or variable road pricing) refers to tolls that are assessed according to the time of day and/or the congestion of the road. Motorists pay higher prices to travel under congested conditions and lower prices at less congested times and locations. The goal of congestion pricing is to reduce peak-period vehicle trips. Tolls can vary based on a fixed schedule or can be dynamic, meaning that rates change depending on the level of congestion that exists at a particular time. This measure can be implemented when new road tolls are implemented to raise revenue, or on existing roadways as a demand management strategy to avoid the need to add capacity. Some highways have a combination of unpriced lanes and Value Priced lanes, allowing motorists to choose between driving in congestion and paying a toll for an uncongested trip.[58]

Limiting the growth in VMT can best be achieved at the regional, state, or local level, using a combination of public transit, transit-oriented land-use development, in-fill development, and urban revitalization. As shown in Figure 2.15, a study by the Center for Clean Air Policy illustrates the potential VMT/day impact of policies at the corridor, area and site scale assuming 500,000 trips/day, 100,000 trips/day, and 5,000trips/day, respectively. However, because each effect is dependent on the characteristics of the community and the type of proposed policy or project, it is difficult to estimate the impact of any one smart growth or transit strategy within a given jurisdiction.

---

[56] Department of Energy, Energy Efficiency and Renewable Energy: Ways To Reduce VMT http://www.eere.energy.gov/EE/trans_reducing_miles.html.
[57] http://www.environmentaldefense.org/article.cfm?contentid=2205.
[58] Victoria Transport Policy Institute: Road Pricing, Congestion Pricing, Value Pricing, Toll Roads and HOT Lanes http://www.vtpi.org/tdm/tdm35.htm.

Figure 2.15: Potential VMT Impact of Policies at Corridor, area and site scale assuming 500,000 trips/day, 100,000 trips/day, 5,000trips/day[59]



Source: Center for Clean Air Policy, Transportation Emissions Guidebook

Many of the states and provinces have identified reducing VMT as an important way to reduce GHG emissions from the transportation sector. A brief summary of existing state and provincial VMT actions is listed here:

Connecticut

Slowing VMT growth is an explicit goal in Connecticut's Climate Action Plan which seeks to double transit ridership by 2020, considering new funding mechanisms for transit investments such as road pricing, redirecting at least 25% of new development to growth-appropriate locations, studying a potential road-pricing pilot study, and VMT reduction incentives such as commuter choices, location-efficient mortgages and mileage based insurance. Connecticut hopes that the package of transit improvements and land-use policies will help achieve a 3% reduction in VMT below the 2020 baseline.[60]

Maine

In Maine's climate action plan, policy actions include working with municipalities, developers and home builders to design and build more energy efficient patterns of development, including neighborhood designs to reduce VMT and support alternative modes of transportation. In addition, the plan calls for developing systems for walkways and public transit vans.[61]

Massachusetts

Massachusetts's Action Plan favors transit-oriented development around transit stations, including energy use and GHG emissions data as criteria in transportation decisions, using sustainable development principles to integrate transportation and land use, increasing parking at train stations to encourage use of public transit, improving the efficiency of transit vehicle movement and developing new bicycle and pedestrian policies.[62] The state's "Take the T to Work program" provides no-down-payment mortgages for qualified applicants who regularly use the state's mass transit system.

---

[59] Center for Clean Air Policy: CCAP Transportation Emissions Guidebook, p. 8 .
[60] Connecticut Climate Action Plan 2005. http://www.ctclimatechange.com/.
[61] Maine http://mainegov-images.informe.org/spo/pubs/origpdf/pdf/ClimateReport.pdf.
[62] Massachusetts Climate Protection Plan 2004 http://www.mass.gov/Eocd/docs/pdfs/fullcolorclimateplan.pdf.

New Hampshire

The New Hampshire Department of Transportation has built bikeways and walkways and promoted pricing measures such as providing cash to employees who do not drive to work and charging for market-based parking at offices, malls and apartment buildings. In addition, the Governor established the New Hampshire Integrated Transportation and Rail Advisory Council in 2000 to enhance alternative transportation and eventually reduce VMT in the state.[63]

Rhode Island

Rhode Island's strategies include: increasing transit oriented development, expanding bicycle/pedestrian infrastructure, commuting trip reduction initiatives such as providing incentives for flex time and telecommuting, VMT based insurance premium structures, the potential electrification of commuter rail and light rail and advanced bus rapid transit as "priority study options."

Vermont

Vermont's VMT policies include encouraging the use of commuter lots, shifting –to bus, vanpool, and train, encouraging telecommuting, encouraging high-density, mixed-use land use planning and pay-at-the-pump auto liability insurance (RUD).[64]

New Brunswick

New Brunswick has not yet published a climate action plan nor has it placed reductions in the transportation sector high on a list of political priorities.

Newfoundland and Labrador

Newfoundland and Labrador's Climate Action Plan lists several ways to reduce emissions from transportation, but does not specifically address steps to reduce VMT.[65] Newfoundland and Labrador's Climate Action Plan acknowledges that while mass transportation has been a challenge in this very sparsely populated province, the government is committed to educating the public about the impact of individual choices on the environment and encourage efficiencies where possible.

Nova Scotia

The Nova Scotia government has proposed initiatives including establishing better links between urban systems and outlying communities with a bus rapid transit program.[66] Mass transit ridership on the Nova Scotia Transit has modestly increased due to the province's partnership with local groups in a program to promote sustainable modes of transportation.[67]

---

[63]The Climate Change Challenge: Actions New Hampshire Can Take to Reduce Greenhouse Gas Emissions," http://www.des.state.nh.us/ard/climatechange/challenge.pdf.
[64] Fueling Vermont's Future: Comprehensive Energy Plan and Greenhouse Gas Action Plan Pursuant to 30 V.S.A. §202b July 1998.
[65] www.conservationcouncil.ca/climate/ files/NEGECP05_FinalReportCard05_en.pdf.
[66] Systems Nova Scotia Energy : Smart Choices for Developing Sustainable Transportation, http://www.gov.ns.ca/energy/files/drm/c43a2718-54e5-4b87-b04e-f7fbd5611d4c.pdf.
[67] New England and Eastern Canada 2005 Report Card on Climate Change Action, Jed Thorp, Clean Water Fund, Massachusetts http://www.ecologyaction.ca/energy_issues/FinalReportCard05English(NS).pdf.

Prince Edward Island

PEI's Memorandum of Understanding for Cooperation on Addressing Climate Change with Canada does not specify how to achieve emissions reductions from transportation.[68] As a result, the Environmental Coalition of Prince Edward Island developed the Sustainable Transportation Initiative which aims to identify barriers to alternative modes of transportation, encourage the use of alternative methods of transportation, establish a ride sharing network and offer businesses energy use assessments and recommendations on the reduction of energy use.

Quebec

The Quebec Government intends to promote the use of mass transit and car-pooling and make major investments in mass transit infrastructures. Within the framework of the *Plan de gestion des déplacements de la région métropolitaine de Montréal* and the *Plan de transport de l'agglomération de la Capitale Nationale du Québec*, the Quebec Government has already announced a program of basic investments in the major mass transit infrastructures for the next ten years. Part of the investments will serve to extend the subway train system (metro), development of reserved lanes, regional terminuses and parking areas that allow intermodal transportation, commuter rail systems, etc.[69]

Implementation

States and provinces should develop broad and forward-thinking land use and transportation plans in order to stabilize the year-to-year growth in VMT.

Land use and transportation policies are integrally related and should be aligned to achieve the same goals of minimizing our dependence on automobile travel, reducing development pressure on remaining open spaces, and revitalizing urban areas. As outlined in the Center for Clean Air Policy's smart growth study, comprehensive regional planning is a crucial first step for improving the sustainability of the transportation system. A regional "visioning" process can engage community members in developing alternative growth scenarios with different land use allocations and transportation options. By requiring alternative scenario analyses for Transportation Improvement Plans (TIPs) and Long Range Transportation Plans (LRTPs), many factors that influence development and infrastructure policy decisions can be identified and relevant impacts can be quantified (congestion, emissions, health, costs).[70] By adopting specific goals for the management of vehicle travel and implementing that goal through a series of local and regional appropriate policies, states and provinces can help meet their GHG emission goals.

Enhancing public transportation services is a second path to reducing VMT that requires addressing both short-term operational challenges and broader, long-term strategies. The goal of such strategies should be to expand and make mass transit more convenient by means of urban planning, zoning and land-use policies. Over the longer term, states and provinces should direct investments in transportation and other infrastructure toward designated growth areas near existing population centers or designated high-growth areas.

[68] Memorandum of Understanding for Cooperation on Addressing Climate Change http://www.climatechange.gc.ca/english/publications/mou_pei/.

[69] Quebec Action Plan on Climate Change 2000-2002, http://www.nccp.ca/NCCP/pdf/media/JMM-qc-en.pdf.

[70] Two for the Price of One: Clean Air and Smart Growth, Forum Recommendations, the Center for Clean Air Policy, March 2005, http://www.ccap.org/pdf/Clean%20Air%20Smart%20Growth%20Forum%20Recommendations%20(Final).pdf.

Priority 8: Reduce Emissions from Heavy-Duty Vehicles

By: Michael Stoddard, Alice Liddell and Madeleine Weil

Source: Ed Jackson, Carl Vinson Institute of Government, University of Georgia.

This section of the Roadmap covers policy recommendations for the heavy-duty transportation fleet – trucks, buses, ships, locomotives, and aircraft – as well as heavy-duty non-road vehicles used for construction, farming and mining. U.S. DOE's Energy Information Administration expects CO_2 emissions from the transportation sector to grow by approximately 45% between 2003 and 2030 and heavy-duty fleets' activity growth rates are projected to outpace even those of light-duty passenger vehicles.[71] Most of the heavy-duty vehicle emissions growth is expected to come from freight movements (as opposed to passenger movements):

Table 2.12: Projected activity growth rates, United States, 2003-2030[72]

Fleet	Activity Unit	Avg. Annual Growth	Total Growth
Light-Duty Vehicles (< 8500 lbs)	(billion vehicle miles traveled)	1.8%	59.3%
Commercial Light Trucks	(billion vehicle miles traveled)	2.0%	74.2%
Freight Trucks (> 10000 lbs)	(billion vehicle miles traveled)	2.3%	91.0%
Air	(billion seat miles available)	1.8%	70.4%
Rail	(billion ton miles traveled)	1.7%	61.4%
Domestic Shipping	(billion ton miles traveled)	1.0%	38.0%

Source: U.S. DOE, Energy Information Administration, Annual Energy Outlook (2006)

Measured in absolute terms, most of this transportation is occurring in the shipment of freight across North American highways.

[71] Energy Information Administration, Annual Energy Outlook 2006 with Projections to 2030, February 2006 (DOE/EIA-0383 2006), http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

[72] Based on projections in: http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_7.xls.

Table 2.13: Freight Shipments by Weight and Value[73]

	Tons (millions)			Value ($ billions)		
	1998	2010	2020	1998	2010	2020
Domestic						
Air	9	18	26	545	1,308	2,246
Highway	10,439	14,930	18,130	6,656	12,746	20,241
Rail	1,954	2,528	2,894	530	848	1,230
Water	1,082	1,345	1,487	146	250	358
International						
Air	9	16	24	530	1,182	2,259
Highway	419	733	1,069	772	1,724	3,131
Rail	358	518	699	116	248	432
Water	136	199	260	17	34	57
Total	**15,271**	**21,376**	**25,848**	**9,312**	**18,339**	**29,954**

Source: Federal Highway Administration, Office of Freight Management and Operations, Freight Facts and Figures (2004)

If recent trends are any indication of the future, we cannot expect near-term efficiency improvements alone to compensate for the GHG impact of activity growth rates. Between 1993 and 2002, heavy-duty truck ton-miles increased 55.5%, but GHG emissions increased 57% over approximately the same period, indicating a slight decrease in fuel economy.[74] Trucks' share of total freight ton miles has increased from 26% in 1993 to 32% in 2002. The increasing utilization of trucks for goods movement relative to other modes (rail, marine) reflects macro-economic changes and infrastructure constraints that are unlikely to change in the near future in a business-as-usual scenario.[75] Truck crossings between the U.S. and Canada are projected to increase 63% by 2020, with New England and Eastern Canada's share of total cross-border truck traffic projected to increase from 6.8% to 9.4%.[76]

Meanwhile, the fuel efficiency of heavy-duty trucks has decreased slightly in recent years, falling from 6.0 mpg in 1990 to 5.7 mpg in 2003.[77] The new U.S. EPA heavy-duty engine emission standards (phased in starting in 2007), while reducing emissions of particulate matter (PM) and nitrogen oxides (NOx) emissions from new trucks by 90%, may actually decrease fuel economy by as much as 5%.[78]

The basic opportunities to reduce GHGs in the heavy-duty vehicle sector are the same as those in the light-duty vehicle sector:

- make heavy-duty vehicle engines as clean as possible by reducing the emissions rate of GHGs and global warming aerosols and by transitioning to lower carbon fuels;
- make heavy-duty vehicles as efficient as possible;
- use these vehicles as efficiently as possible and reduce vehicle miles traveled.

Certain important emissions policy solutions for heavy-duty vehicles are better suited for federal rather than state, provincial or regional action, such as extending the CAFE fuel economy approach to heavy-duty vehicles. Extending California's tailpipe emission standards for cars and light trucks – the

[73] Adapted from Table 2-1, "Freight Shipments by Weight and Value" in Freight Facts and Figures 2004, Office of Freight Management and Operations, Federal Highway Administration. Shipments moved via pipeline have been excluded.

[74] U.S. Environmental Protection Agency, *Greenhouse Gas Emissions from the U.S. Transportation Sector, 1990-2003,* March 2006 (EPA 420 R 06 003), http://www.epa.gov/otaq/climate/420r06003.pdf, p. 18.

[75] The trend toward e-commerce and just-in-time delivery has resulted in smaller shipment sizes and increased VMT. Economic globalization has meant that there is less demand for bulk commodity shipments (appropriate for train and marine movements) compared to lower-weight, higher-value product shipments (appropriate for truck movements).

[76] http://www.ebtc.info/PDF/Executive%20summary.pdf.

[77] EPA, p. 18.

[78] Ravi Krishnan and T.J. Tarabulski, *Economics of Emission Reduction For Heavy Duty Trucks*, January 2005, DieselNet Technical Report, http://www.dieselnet.com/papers/0501krishnan/.

Greenhouse Gas Emission Standards for Vehicles – to heavy trucks is probably also better suited for federal action. California has established no such precedent, and state-based standards for expensive heavy-duty vehicles may have a greater tendency to push consumers to shop out of state than would be the case for light vehicles.

That leaves the following actions which are best suited for the state, provincial and regional levels:

- reduce black carbon emissions from in-use diesel engines;
- promote improved efficiency of heavy-duty vehicles;
- improve the efficiency of the region's freight transportation system;
- promote the transition to cleaner fuels or energy carriers (see section on transportation fuels, Priority 6).

8.1 Reduce Black Carbon Emissions from In-Use Diesel Engines

Summary

Each state and province in the region should establish a 10-year strategic plan to achieve the maximum reduction in health risk from diesel soot. The objective of the plans should be to complement federal regulations by retrofitting aftermarket emission controls onto existing engines. These plans should establish targets for emission reductions and deadlines, recommend legislation or regulations where appropriate, and establish a steady source of funding to help defray the cost of retrofits during the 10-year period. We also recommend adopting anti-idling rules for all on-road vehicles and for those non-road vehicles that have the potential to access idling alternatives such as auxiliary power units or shore power.

By retrofitting existing non-road and on-road diesel engines with emission controls, states and provinces can cut dangerous diesel particulate matter (PM2.5) pollution by between 50%-90% per engine. Over the next decade, such cuts could achieve a proportionate reduction in emissions of black carbon, which has a global warming potential equivalent to roughly 600 times that of CO_2.

The U.S. and Canadian regulations take care of "new" engines entering the fleet. EPA projects that the full effect of these standards will be achieved by the year 2030, when nearly all existing on-road and non-road engines in the affected classes finally will have been retired and replaced with 2007 or 2008 and later model years that meet the new standards. However, in the intervening 25 years, a significant portion of the existing, long-lived diesel fleet will continue to operate at the older, dirtier pollution standards.

Currently, the emissions of diesel fine particulates in New England and Eastern Canada are nearly 24,500 tons per year. The health impacts from these emissions in New England alone are estimated at more than 16,000 asthma attacks, 1,238 non-fatal heart attacks, and 789 lives cut short (on average, 14 years shorter than normal) -- each year.

Retrofitting emission controls onto in-use engines and implementing an aggressive campaign to eliminate unnecessary engine idling can cut emissions of PM2.5 and save the equivalent of about 4 $MMTCO_2e$.

Opportunity

Everywhere one looks there are examples of diesel engines whose sooty exhaust contributes to global warming and increased health risks. Trucks that we sit behind in traffic, buses that take children to school and bulldozers on construction sites are powered by diesel engines. Diesel engines also power transit buses, passenger trains, garbage trucks and marine vessels. Commerce and transportation rely on the diesel engine because it is durable, reliable, powerful and more fuel efficient than the gasoline engine.

Reduce Health Risk

Despite their abundance and the frequency with which average citizens are exposed to them, these engines and their fuels are among the last in the U.S. and Canada to be regulated for their impacts on air pollution. This is problematic because the contribution by diesel engines to emissions of air toxics, fine particulates and nitrogen oxides in our communities is very high and is projected to cause more premature deaths (in the U.S.) due to cancer, respiratory and cardiac disease than either homicides or drunk driving.[79]

Combustion of diesel fuels in on-road and off-road diesel engines resulted in PM2.5 emissions, shown in Table 2.14, as estimated by U.S. and Canadian federal agencies.

Table 2.14: PM2.5 Emissions from On-Road and Off-Road Diesel Engines[80]

States/Provinces	Highway Diesel Vehicles	Off-Road Use of Diesel	Total 2.5 Emissions
Connecticut	904	952	1,856
Maine	609	456	1,065
Massachusetts	1,373	3,485	4,859
New Hampshire	315	315	630
Rhode Island	73	200	273
Vermont	282	245	527
New Brunswick	670	778	1,448
Newf. - Labrador	255	368	623
Nova Scotia	471	653	1,124
PEI	154	294	448
Quebec	4,420	7,183	11,603
Total	9,526	14,930	24,456

As a result of these diesel emissions, the estimated health impacts in New England alone are surprisingly high and costly.

Table 2.15: Estimated Annual Health Impacts from Diesel Pollution in New England[81]

[79] Clean Air Task Force, *Diesel and Health in America: The Lingering Threat*, Feb., 2005, p. 5, indicates that total projected premature (14 years on average) mortality from diesel fine particulates, in the U.S., is 21,000 per year.
[80] New England States emissions 2002 data using 2002 MANE-VU Emissions. PM 2.5 converted from tons to metric tons at .9078474; Canada Provinces emissions 2000 data from Environment Canada.
[81] Adapted from Clean Air Task Force, *Diesel and Health in America, Diesel Soot Impacts*, at http://www.catf.us/projects/diesel/dieselhealth/national.php?site=4 .

State	Premature Death	Heart Attack (non fatal)	Asthma Attack
Connecticut	206	340	4,091
Maine	24	36	437
Massachusetts	475	727	9,925
New Hampshire	51	79	935
Rhode Island	24	41	563
Vermont	9	15	192
Total	789	1,238	16,143

Reduce Climate Impact of Black Carbon

PM2.5 that comes from combustion is relevant to climate change because a portion of the particulate matter, called “black carbon” (or “soot”) from diesel emissions has a global warming potential (GWP_{100}) of about 600 times that of CO_2.[82]

Black Carbon (BC) is a product of incomplete combustion from diesel fuels, coal, biofuels and biomass burning. As an aerosol (not a gas), it warms via a different mechanism than GHGs. Its dark color makes it a potent absorber of energy from the sun, which it converts to heat. It also has a short atmospheric lifetime of about one week.

The climate effects of black carbon in the atmosphere are dependent upon a number of processes, some of which are better understood than others. These include how black carbon mixes with other aerosols; what other aerosols are co-emitted with the black carbon and in what proportion; how its composition changes after emissions; its impact on clouds and precipitation; and its spatial relationship to clouds. Global impacts, including the transferring of heat may differ from regional impacts, such as the creation of more cloud cover. There are enough uncertainties about the atmospheric behavior that there is not consensus in the research community. However, based on the ratio of co-emitted aerosols, diesel sources appear to have a larger warming impact than other black carbon sources.[83]

The warming impact can persist once deposited on snow or ice. It has been found to accelerate the melting of snow and ice by darkening the surface, which reduces the snow’s albedo (the amount of solar energy reflected back to space) and causes more heat to be retained.[84] In these ways, the effects from BC can cause a “feedback loop,” a cycle that can speed up the rate of change in atmospheric temperatures and ocean currents, which in turn leads to faster warming, melting and other climate changes. As a result, BC may be contributing to trends toward earlier springs in the Northern Hemisphere, thinning Arctic sea ice, and melting glaciers and permafrost.[85]

---

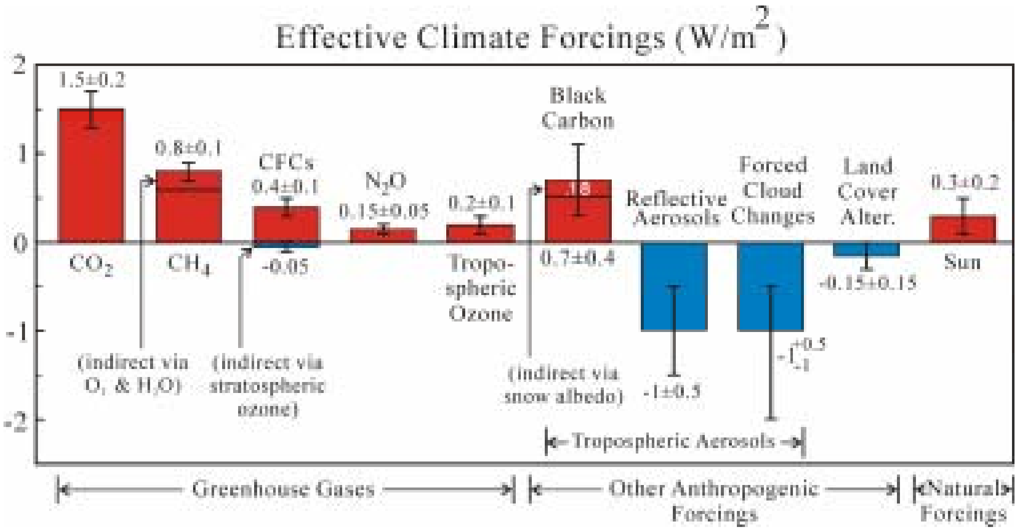
[82] Bond, T. and Haolin, Sun, “Can Reducing Black Carbon Emissions Counteract Global Warming?” *ES&T*, August 2005, p. 5921, estimating GWP100 of 680, from which we have subtracted 80 to account for the reflective organic carbon component; *see also* Bond, Venkataraman, Masera, “Global atmospheric impacts of residential fuels,” *Energy for Sustainable Development*, July 2004.

[83] Hansen, J. *et al.* 2005. “Efficacy of climate forcings.” *J. Geophys. Res.* **110**, D18104, doi:10.1029/2005JD005776.

[84] The albedo, sometimes expressed as a percentage from 0% to 100%, is the ratio of reflected/scattered power to incident power, and refers to an average across the spectrum of visible light. Fresh snow albedos are high: up to 90%. The ocean surface has a low albedo. The average albedo of earth is about 30%.

[85] Hansen, J., and L. Nazarenko. 2004. Soot climate forcing via snow and ice albedos. *Proc. Natl. Acad. Sci.* **101**, 423-428, doi:10.1073/pnas.2237157100.

Figure 2.16: Effective Climate Forcings (W/m^2) [86]



Source: Hansen *et al.*, Efficacy of climate forcings (2005)

In Figure 2.16, bars represent cumulative warming (red) and cooling (blue) effects on the atmosphere, in Watts per square meter, from emissions of certain gases, aerosols and natural forcings, from all activities between the years 1750 and 2000, inclusive.

As noted above, the NE-EC region experienced nearly 24,500 metric tons of PM2.5 from diesel engines per year in 2002. We estimate that the BC portion of this diesel PM2.5 was approximately half of the total PM2.5, or about 12,250 metric tons.[87] With a warming effect roughly 600 times that of CO_2, we estimate that this amount of BC from diesels has a short-term warming impact equivalent to more than 7 million metric tons of CO_2 (MMTCO2e)

We further estimate that aggressive state and provincial retrofit programs, combined with the federal regulations just now starting to take effect, can cut these emissions by 50-60% in the next 10-15 years. Such cuts would have proportionate short-term cooling effect roughly equivalent to reducing CO_2 emissions by about 4 MMTCO2e.

Filling the Void in Federal Rules

The more specific opportunities for policy change relate to addressing two challenges.

First, the recently adopted federal emission standards only apply to the sale of "new" diesel engines, but do not apply to the millions of engines already "in-use" (*i.e.*, sold before 2007 and 2008 when the new standards take effect).

In 2002, the U.S. EPA promulgated a regulation that set strict emission standards on the sale of heavy-duty on-road ("highway") diesel engines beginning with model year 2007 engines. Essential aspects of these regulations include lowering the sulfur content in the on-road diesel fuel from 500 down to 15 parts per million (ppm), a 97% reduction, and setting emission (tailpipe) standards of 0.1 grams

[86] Hansen, J. *et al.* "Efficacy of Climate Forcings."

[87] Assuming that 50% of PM2.5 from diesels is in the form of black carbon, *see*, Shah, S. D., Cocker, Miller and Norbeck (2004), "Emission rates of particulate matter and elemental and organic carbon from in-use diesel engines," *Environmental Science & Technology 38*(9): 2544-2550; Kirchstetter, T., "On-road measurement of fine particle and nitrogen oxide emissions from light- and heavy-duty motor vehicles," Atmospheric Environment 33 (1999) 2955-2968.

PM2.5/brake horsepower-hour (g/bhp-hr) and .20 g/bhp-hr for NOx.[88] These tailpipe emission reductions of PM2.5 deliver a 90% reduction from the standard for engines built between 1994 and 2006, and a 99% improvement over engines built from 1991-1993. In 2004, Environment Canada adopted standards and implementation timelines that mirror the EPA rule.[89]

In 2004, EPA promulgated a companion regulation for the sale of heavy-duty non-road diesel engines beginning with model year 2008 engines. Non-road engines covered by the rule include engines used in construction, farming and mining. The rule does not cover locomotive engines and certain classes of marine vessel engines. The standard set in the rules limits emissions of PM2.5 to .01 g/bhp-hr and emissions of NOx to .3 g/bhp-hr for most engines.[90] In 2005, Environment Canada incorporated the EPA standards and implementation timelines for this class of diesel engines.[91]

The U.S. and Canadian regulations take care of "new" engines entering the fleet. EPA projects that the full effect of these standards will be achieved by the year 2030, when nearly all existing on-road and non-road engines in the affected classes finally will have been retired and replaced with 2007 or 2008 and later model years that meet the new standards. However, in the intervening 25 years, a significant portion of the existing, long-lived diesel fleet will continue to operate at the older, dirtier pollution standards.

The opportunity presented here is to retrofit commercially available pollution control devices on the dirtiest engines and on those that pose the greatest risk to human health.

Second, for all types of diesel engines it remains customary to let the engines idle even when not needed, all the time emitting BC and CO_2. There is no federal rule prohibiting such idling, which presents another opportunity for state and provincial action.

In addition to the U.S. and Canadian federal laws to reduce PM2.5, the New England states and Eastern Canadian provinces passed a resolution to help reduce diesel emissions. At the 28th Annual Conference of New England Governors and Eastern Canadian Premiers in 2003, the Resolution Concerning Environmental Projects and Issues was adopted. This Resolution lent support to the view that policy

---

[88] EPA On-Road Rule, 40 CFR Parts 69, 80, and 86 Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements; Final Rule [AMS–FRL–6923–7] RIN 2060–AI69.

[89] Environment Canada Rule "Sulfur in Diesel Fuel Regulations" SOR/2002-253 to 283 and SI/2002-105 to 106; On-Road Vehicle and Engine Emission Regulations, SOR 2003-2, 12 December, 2002.

[90] EPA Non-Road Rule, 40 CFR Parts 9, 69, 80, 86, 89, 94, 1039, 1048, 1051, 1065, and 1068 [OAR–2003–0012; FRL–7662–4] RIN 2060–AK27 Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel. EPA regulations: For engines less than 25 hp, PM of 0.30 g/bhp-hr (grams per brake-horsepower-hour) beginning in 2008, and leaving the previously-set 5.6 g/bhp-hr combined standard for NMHC+NOx in place. For engines of 25 to 75 hp, EPA is adopting standards reflecting approximately 50 percent reductions in PM control from today's engines, again applicable beginning in 2008. Then, starting in 2013, standards of 0.02 g/bhp-hr for PM and 3.5 g/bhphr for NMHC+NOx will apply for this power category. For engines of 75 to 175 hp, the standards will be 0.01 g/bhp-hr for PM, 0.30 g/bhp-hr for NOx and 0.14 g/bhp-hr for NMHC starting in 2012, with the NOx and NMHC standards phased in over a period of three to four years in order to address lead time, workload, and feasibility considerations. These same standards will apply to engines of 175 to 750 hp as well starting in 2011, with a similar phase-in. These PM, NOx, and NMHC standards and phase-in schedules are similar in stringency to the 2007 highway diesel standards and are expected to require the use of high efficiency after treatment systems to ensure compliance. For engines above 750 hp, EPA is requiring PM and NMHC control to 0.075 g/bhp-hr and 0.30 g/bhp-hr, respectively, starting in 2011. More stringent standards take effect in 2015 with PM standards of 0.02 g/bhp-hr (for engines used in generator sets) and 0.03 g/bhp-hr (for non-generator set engines), and an NMHC standard of 0.14 g/bhphr. The NOx standard in 2011 will be 0.50 g/bhp-hr for generator set engines above 1200 hp, and 2.6 g/bhp-hr for all other engines in the above 750 hp category. This application of advanced NOx emission control technologies to generator set engines above 1200 hp will provide substantial NOx reductions and will occur earlier than we had proposed in the NPRM. In 2015, the 750–1200 hp generator set engines will be added to the stringent 0.50 g/bhp-hr NOx requirement as well. *See generally*, http://www.epa.gov/otaq/url-fr/fr29jn04.pdf.

[91] *Off-Road Compression-Ignition Engine Emission Regulations*, SOR 2005-32 February 8, 2005.

makers appreciate the environmental risks associated with diesel pollution by directing the Conference Committee on the Environment to:

> pursue appropriate options to reduce diesel emissions; encourage the early introduction of cleaner diesel fuels in the region; promote anti-idling initiatives; and enhance education for the public on the benefits of diesel clean-up programs.[92]

The overarching opportunity presented by cleaning up pollution from diesel engines is that between now and 2020 we can take action with respect to the current diesel fleet and rapidly reduce a very serious health risk while at the same time diminishing the risk of warming and melting feedback loops caused by black carbon. By the year 2030, nearly all on-road and non-road diesel engines currently in operation today will have been retired and replaced with new engines built to U.S. EPA's recently adopted standards requiring engines to emit 90% less PM and 90% less NOx than current models.[93]

A related emerging opportunity is for diesel pollution mitigation strategies to assist states in achieving national ambient air quality standards (NAAQS). In Connecticut, for example, two counties have been determined to be in non-attainment of these standards for PM2.5, and diesel mitigation measures may help the state meet its obligation to develop a State Implementation Plan for compliance.

Implementation

To minimize health risk from diesel soot, states and provinces of the region should maximize reductions by:

- instituting a 10-year plan to retrofit in-use diesel engines with the best available control technology;
- adopting anti-idling rules.

Retrofit In-Use Diesel Engines

Each state and province in the region should establish a 10-year strategic plan to achieve the maximum reduction in health risk from diesel soot. The objective of the plans should be to complement federal regulations by retrofitting aftermarket pollution controls onto existing engines. These plans should establish targets for emission reductions and deadlines, recommend legislation or regulations where appropriate, and establish a steady source of funding to help defray the cost of retrofits during the 10-year period.

---

92 Resolution 28-7, Resolution Concerning Environmental Projects and Issues, Sept. 9, 2003.

93 Through its clean diesel truck and buses program, EPA reduced the level of sulfur in highway diesel fuel by 97 percent starting in 2006, and will reduce NOx emissions by over 90%. http://www.epa.gov/air/urbanair/nox/effrt.html EPA's new program will, over time, require new engines to result in PM and NOx emission levels that are 90 percent and 95 percent below today's levels, respectively. http://www.epa.gov/otaq/regs/hd2007/frm/f00057.pdf.

Example: Diesel Policies, California and New Jersey

California, Connecticut and New Jersey are examples of states that have adopted legislation mandating a comprehensive approach to retrofitting diesel engines.

California, after identifying diesel PM as a toxic air contaminant in 1998, adopted the Diesel Risk Reduction Plan to reduce diesel PM emissions and resultant health risk to "near zero" by 2020.[94] Pursuant to that plan, the California Air Resources Board has (CARB) has established through regulation a timeline for cleaning up priority fleets. CARB has adopted separate rulemakings to clean up all fleets of public transit buses and solid waste collection vehicles and is in the midst of new rulemakings to clean up all fleets of school buses, on-road fleet vehicles owned by public agencies or utilities and certain non-road fleet engines (such as commercial harbor craft and marine vessels, and cargo handling equipment at ports). The rules so far adopted require fleets to achieve "best available control technology" and phase in this requirement over a period of years. Compliance is achieved by pursuing any combination of retrofitting pollution controls certified to cut PM emissions by at least 85%, retiring older engines and replacing them with new ones, or using clean, alternative-fuel engines. To supplement the regulatory approach, California also established a state and local partnership incentive program that pays the incremental cost of diesel retrofits and early retirement/replacement of existing engines. The Carl Moyer Fund now receives a steady revenue stream from a combination of vehicle inspection fees, registration fees, tire fees and some state budget appropriations.

New York City has also moved aggressively to regulate the clean up of existing diesel engines. In the past year, the City adopted a suite of laws requiring transit buses, school buses, tour buses, publicly owned heavy-duty diesels and publicly contracted construction equipment to use ultra-low sulfur diesel fuel and the best available technology (BAT) for after treatment (retrofit) pollution control.[95] For transit and tour buses and sanitation trucks, installing best available technology should result in at least 85% reductions of both PM2.5 and black carbon. For school buses and construction equipment, BAT will likely deliver PM2.5 reductions in the 20-60% range. This is lower than the reductions in the other fleets but it will be very important from a health perspective because people are exposed to high volumes of PM from these particular vehicles, especially in densely populated areas.

To maximize reductions of diesel PM2.5, the strategic plans of each state and province should include an inventory of heavy-duty diesel engines registered in their jurisdiction and an estimate of current the emissions from these engines. Targets of 75% reductions should be set for publicly owned, operated or contracted fleets and other fleets that present a significant exposure risk to large or sensitive population centers (such as hospitals, schools, dense neighborhoods, or business districts). To improve cost-effectiveness, emphasis also should be placed on retrofitting those individual engines that currently emit the most but have the longest useful life remaining (*i.e.*, those that will not need to be rebuilt or replaced in the near future). Where costs of retrofitting can be easily passed on to customers (or taxpayers), a firm regulatory approach is likely to be the most cost-effective method of achieving reductions. Where establishing this type of payment system would be more difficult, or where there is significant risk of putting certain fleets at a competitive disadvantage, more emphasis should be put on providing financial incentives to defray the cost of retrofits.

Employ Anti-Idling Measures

Eliminating avoidable idling from heavy diesel engines saves fuel costs and reduces noise and exposure to toxic fumes for drivers, job site workers and nearby residents.

Diesel engine operators leave their main engines running even when the vehicle is not in use for two reasons. First, idling is the longtime custom of diesel operators to warm up the diesel engine (and keep it warm). Second, the vehicle needs a source of energy to operate systems on board other than the

---

94 California Diesel Risk Reduction Program, http://www.arb.ca.gov/diesel/mobile.htm.
95 New York City Local Law 42 [school buses] http://www.nyccouncil.info/pdf_files/bills/law05042.pdf, New York City Local Law 77 [construction equipment] http://www.ecy.wa.gov/programs/air/PDFS/NewYorkCity.pdf, Introductory Numbers 414-A, 415-A, 416-A, 417-A and 428-A http://www.ci.nyc.ny.us/html/dep/html/news/innews.html.

propulsion system. Such needs include powering refrigeration/heating units, electronic systems, cranes and pumps or a passenger temperature control system.

New developments in technology make a large percentage of diesel engine idling avoidable. Nearly all modern on-road diesel engines can commence operation without a lengthy warm-up period. Also, there are numerous alternative sources of energy to run on-board systems that are cleaner and in many cases more fuel efficient than running the main propulsion engine.

Each state and province in the region should adopt anti-idling rules for on-road vehicles and for non-road vehicles (*e.g.*, locomotive and marine engines) that have the potential to access to idling alternatives. These rules should provide exceptions to use the main propulsion engines only in situations where it is necessary to operate on-board systems and there are no nearby alternative sources of energy supply.

Example: Connecticut Anti-idling

Connecticut was one of the first states to pass a law restricting idling of diesel engines to 3 minutes. Other states have set the time limit at 5 minutes or 10 minutes, and all provide exceptions for running on-board systems, especially when the outside temperature is very hot or very cold.

There are four important facets of an anti-idling program. It is important that the program be well publicized so that operators have ample notice of where and when the rule applies. Also, there must be an adequate enforcement mechanism that creates a real disincentive for operators to break the rule. Making violation of the anti-idling rule an infraction of traffic laws will give law enforcement officers authority to enforce the rule and maximize compliance. Finally, some of the biggest BC and CO_2 savings will come from providing alternatives for the operation of on-board systems. In the case of large marine vessels, the use of auxiliary power units (APU) or electric shore power can eliminate the need to run large propulsion engines while tied up in port.

8.2 Promote Improved Efficiency of Heavy-Duty Vehicles

Summary

Jurisdictions in the region should establish low-interest loan programs and other financial incentives to promote the purchase and installation of improved engines, vehicles or other equipment that enhances fuel efficiency.

Working together, government and industry representatives have identified a menu of steps that freight hauling trucks can implement to improve their fuel efficiency. The common feature of all measures on the menu is that they are cost-effective, and have fast paybacks, and taken together can reduce GHGs by more than 10 metric tons per vehicle per year. In the short-term, loan programs or other incentives can expedite deployment of these efficiency measures.

In the longer-term, coordinated efforts to promote hybridization could pay large dividends. Next generation heavy-duty vehicles may be capable of increasing fuel efficiency by 100% using hybrid technology. Participants in a public-private partnership studying this opportunity anticipate saving more than 20 million barrels of oil in 2010 and 250 million barrels of oil in 2020, equivalent to approximately 108 $MMTCO_2$ in 2020.

Opportunity

The Energy Information Administration's 2006 Annual Energy Outlook (AEO) predicts that between 2005 and 2030, the fuel efficiency of the U.S. heavy truck fleet will increase by a mere 13%, from 6 mpg to 6.8 mpg.[96] The AEO assumes only modest penetration of fuel efficiency design improvements and behavior modifications capable of significantly enhancing efficiencies in existing and newly designed trucks.

Increasing fuel efficiency for heavy-duty vehicles could have significant economic and environmental benefits. There are a variety of measures that could be implemented in the near term to help lower operating costs for fleet owners while reducing GHG emissions.

Cost-Effective Changes

In the United States, EPA's SmartWay℠ program provides a support framework and training materials for freight carriers pursuing efficiency measures. The SmartWay Transport Partnership is a voluntary collaboration between U.S. EPA and the freight industry designed to increase energy efficiency while significantly reducing greenhouse gases and air pollution. Illustrations of the types of measures, and their potential GHG reductions, are presented in Table 2.16.

Table 2.16: Illustrations of Potential Measures to Increase Energy Efficiency per Truck and the Related GHG Reductions and the Associated Costs

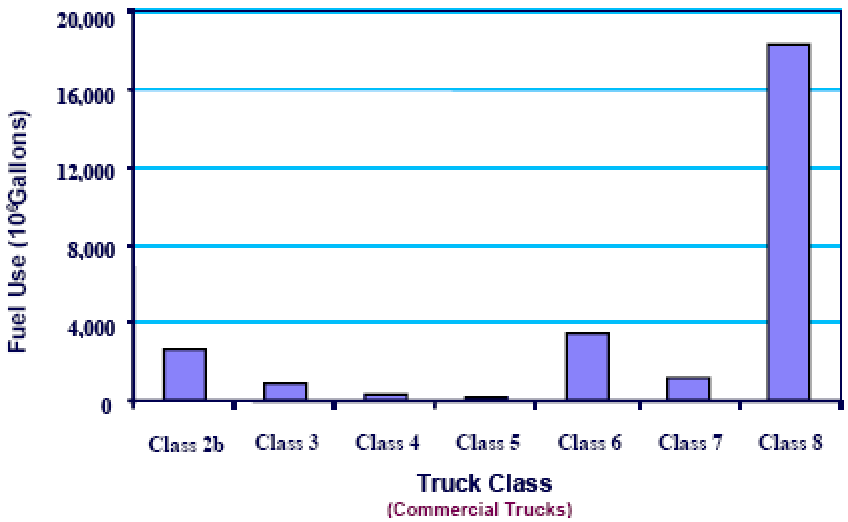
All potential savings apply per truck	Potential fuel economy improvement		GHG reduction potential (metric tons) unless noted		Costs Impacts
	Low	High	Low	High	
Low rolling resistance tires (wide-base tires)	2%	5%		4	Immediate savings of $130 versus two standard wheels on new trucks
Lighter weight components		3%	2	5	Premium of $2000 for tractor and $2000 for trailer
Synthetic engine/drive train lubricants	3%	5%		5	Total cost savings of $500 over year
Reducing highway speed from 70 to 65 mph		7%		7%	reduced productivity could be outweighed by fuel savings and co-benefits
Driver training	5%	18%	8	24	Payback for training and engine monitor 2 years
Idle Reduction (APUs, auto engine idle on/off, truck stop electrification)				19	2-3 year payback for APU
Automatic tire inflation		1%		1	2 year payback through fuel and maintenance savings
Improving aerodynamics		15%		5	Quick payback

Source: EPA SmartWay Transport Partnership

As Figure 2.17 illustrates, fuel use by Class 8 trucks (dump trucks, cement trucks, and heavy tractor trailers) far exceeds use by any other weight class. Therefore, energy efficiency improvements should focus on this weight class.

[96] http://www.eia.doe.gov/oiaf/aeo/supplement/sup_tran.xls. Table 55.

Figure 2.17: Annual Fuel Use by U.S. Commercial Truck Class (Based on VIUS Data)[97]



Source: U.S. DOE, Technology Roadmap for the 21st Century Truck Program (2000)

Hybrid Technology

A heavy-duty hybrid-electric vehicle (HEV), as defined by the 21st Century Truck Partnership, typically features an internal combustion engine (usually diesel), an electric motor/generator, a rechargeable energy storage system (usually batteries and/or ultracapacitors), a power electronics system, and regenerative braking.[98] Hybrid systems are particularly well-suited to applications where frequent braking and acceleration is required, such as in local delivery trucks, garbage trucks or transit buses.

The potential efficiency improvements of heavy-duty hybrids are significant. The National Renewable Energy Laboratory (NREL) and industry partners are working to develop the next generation of heavy-duty hybrids capable of increasing fuel efficiency by 100% using technologies developed by the Advanced Heavy Hybrid Propulsion Systems Project.[99] Project partners anticipate saving more than 20 million barrels of oil in 2010 and 250 million barrels of oil in 2020, (equivalent to approximately 108 $MMTCO_2$ in 2020).

Although in recent years hybrid technology has been successfully commercialized for light-duty vehicles, it has not yet fully emerged as an economically and environmentally competitive alternative in the heavy-duty sector. There are a number of active public-private partnerships pursuing commercialization of hybrid technology for heavy-duty vehicles. The 21st Century Truck Partnership (a government-industry partnership led by the U.S. DOE) is working to achieve market penetration of hybrid powertrain technology by significantly reducing component costs and extending the design life of energy storage systems.[100]

---

[97] Technology Roadmap for the 21st Century Truck Program (December 2000) Figure 3.2 p. 3-2. http://www.eere.energy.gov/vehiclesandfuels/pdfs/program/21ct_roadmap.pdf.
[98] http://www.nrel.gov/vehiclesandfuels/ahhps/technology_basics.html.
[99] http://www.nrel.gov/vehiclesandfuels/ahhps/.
[100] Kenneth Howden, Office of FreedomCAR and Vehicle Technologies, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, *21st Century Truck Partnership*, presented at the Center for Clean Air Policy's Freight Solutions Dialogue: Climate Protection and Clean Air Through Efficiency Goods Movement (June 6, 2005).

The partnership supports research aimed at developing production prototype vehicles that achieve the following objectives by 2010:

- double the Class 8 line-haul truck fuel efficiency on a ton-miles-per-gallon basis;
- triple the Class 2b and 6 truck (delivery van) fuel efficiency on a ton-miles-per-gallon basis;
- triple the fuel efficiency of heavy-duty transit buses on a miles-per-gallon basis.

Example: Hybrid Buses, New York City

DaimlerChrysler Commercial Buses North America has received a contract for 500 Orion VII hybrid-electric buses from New York City transport services. New York City Transit (NYCT) has ordered 216 Orion VII hybrid-electric buses and Metropolitan Transportation Authority (MTA Bus) 284 units. This is the largest order for hybrid buses in history. Orion, DaimlerChrysler's North American city bus brand, will begin deliveries in the second quarter of 2006. Compared to standard diesel propulsion, the hybrid units will provide significantly better fuel economy while greatly reducing emissions: 90% less particulate matter, 40% less NOx, and 30% less GHG. Drivers will enjoy faster acceleration and customers will experience a quieter, smoother ride free of the frequent transmission shifts encountered in conventional buses. The next generation Orion VII hybrid buses purchased by NYCT cost $385,000 per bus, or about $95,000 more than the average NYCT diesel bus.

U.S. EPA sees hydraulic hybrids as particularly well-suited to the heavy-duty market. In these prototype vehicles, the battery and electric motor are replaced by a hydraulic system that harnesses the energy created when the brakes are applied. This technology, under development and patent by U.S. EPA, is expected to reduce fuel consumption in urban delivery trucks by 25-45% in city driving and have a consumer payback of 1-3 years.[101]

Finally, we note that development of hybrid technology for non-road engines is also underway, most notably for locomotives. The East Japan Railway Company plans to start operating a hybrid locomotive with a lithium ion battery during the summer of 2006. Fuel consumption is expected to decrease by 10%.[102] The design anticipates the commercialization of hydrogen fuel cell batteries for train applications. The same company has plans to test a similar model locomotive with a hydrogen fuel cell instead of a battery later this year. For this model, expected fuel savings grow to 20%.[103]

The duty cycles of switcher locomotives make them more suitable to hybrid technology. These engines, called "Goats," push heavy loads over short distances at slow speeds, and idle up to 70% of the time. "Green Goat" hybrid switchers reduce fuel consumption by 40-60%.[104]

Implementation

Some New England states and Eastern Canadian provinces have demonstrated a willingness to offer financial incentives, in addition to those available at the federal level, to encourage market penetration of more efficient light vehicles (*e.g.*, hybrid technology). Our recommendation for the heavy-duty vehicle sector builds on this precedent. We recommend that each state and province in the region assess the most cost-effective opportunities for moving more efficient vehicles, vehicle systems, or accessories (*e.g.*, tires) into the marketplace and consider establishing programs to promote their deployment among the region's commercial freight carriers.

---

[101] U.S. EPA, *Clean Automotive Technology: Innovation that Works*, *http://www.epa.gov/otaq/technology/420f04024.pdf*.
[102] JR East develops lithium-diesel hybrid train, http://asia.news.yahoo.com/060316/kyodo/d8gcb7j00.html.
[103] Japan to Test Fuel Cell-Powered Train (April 14).
[104] RailPower Technologies, Inc., BC, Canada. http://www.railpower.com/dl/GGSeries.pdf.

Low-Interest Loan Program

As a first step, we recommend that each of the New England states and Eastern Canadian provinces establish a truck energy efficiency low-interest loan program. This program should include an outreach component, and financial assistance to truck owners covering additional upfront costs of purchasing and installing energy efficiency features. Since efficiency features like the ones previously listed will pay for themselves over time through avoided fuel costs, owners could be asked to pay back the loans with their savings, and the programs could be run at little net cost to state or provincial treasuries.

Hybrid Technology Incentives

As hybrid technology becomes increasingly viable for the heavy-duty sector, we recommend spurring market penetration by granting sales tax rebates or grants until hybrids become fully cost-competitive with conventional heavy-duty engines. The potential effects of granting additional incentives (*i.e.*, granting hybrid trucks preferential parking or routing opportunities, varied toll structures for future road pricing schemes, etc.) should also be investigated.

8.3 Improve the Efficiency of the Region's Freight Transportation System

Summary

We recommend establishing the goal of shifting 10% truck freight to rail or waterborne modes of transportation. A first step in understanding how to achieve this goal is to complete the ongoing regional freight transport study and expand it to focus more on opportunities to expand waterborne commerce in the region.

Shipping via waterborne or rail modes consumes approximately 89-90% less energy per ton-mile compared to trucks.

Among the potential benefits of pursuing greater inter-modal activity are reductions in air pollution, traffic congestion and road wear.

Opportunity

Although trucks are the dominant means of domestic and U.S – Canadian freight shipments, they are not the most efficient mode. Shipping via waterborne or rail modes consumes approximately 89-90% less energy per ton-mile compared to trucks. Air is the most energy intensive shipment mode, using more than eight times the energy per ton-mile consumed by trucks, and 54-78 times that consumed by waterborne or rail modes.

Figure 2.18: Freight Mode Comparisons of Energy Intensity and Freight Activity[105]

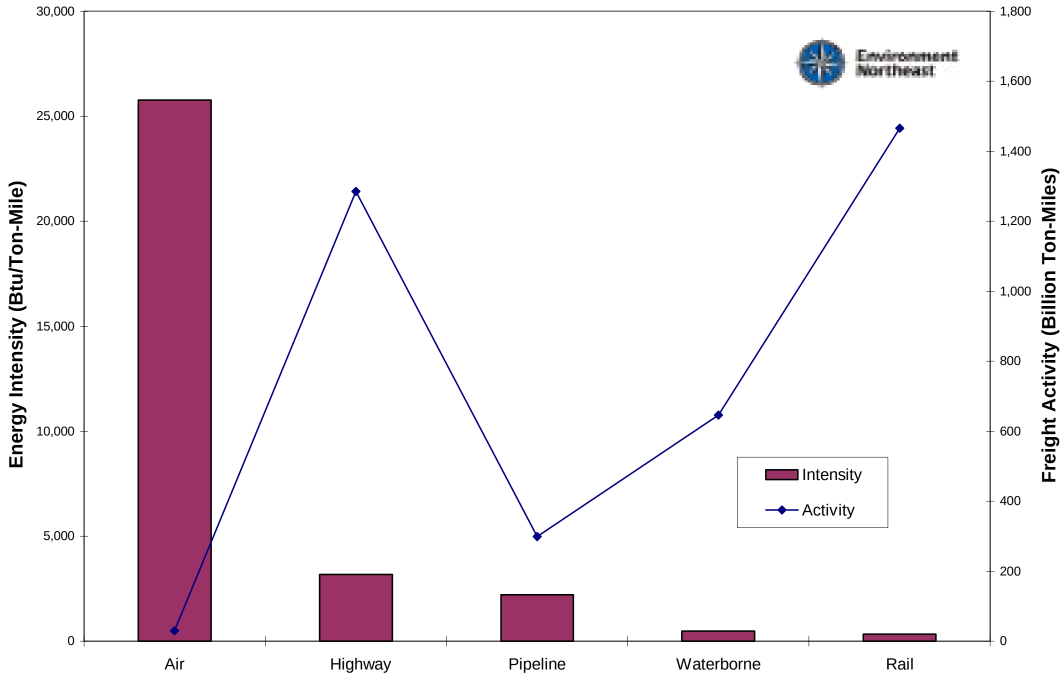
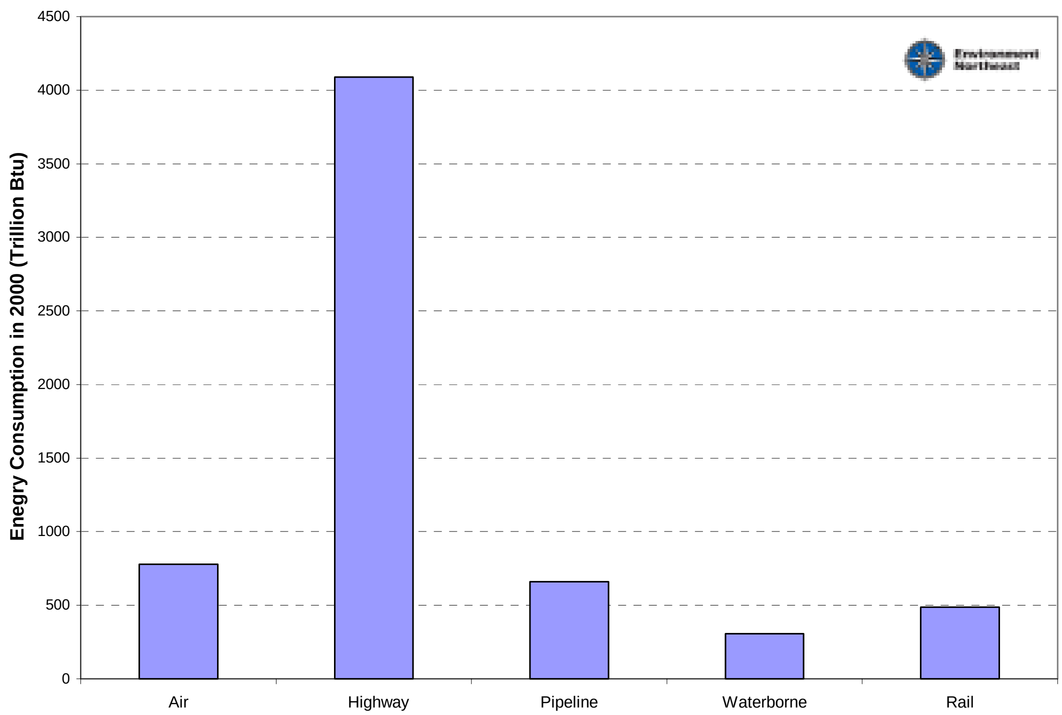


Figure 2.19: Energy Consumption by Freight Mode in 2000[106]

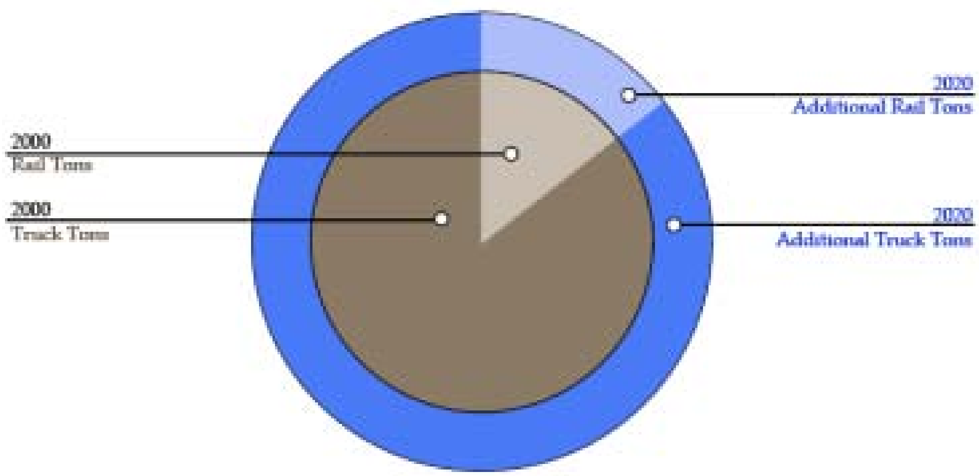


[105] Data calculated from http://intensityindicators.pnl.gov/data-files/transportation_indicators.xls.
[106] *Ibid.*

Opportunities may exist in the NE-EC region to shift freight movements from truck to rail and waterborne modes. Among the potential benefits of pursuing greater inter-modal activity are reductions in air pollution, traffic congestion and road wear.

As previously discussed, the quantity of freight movements in the northeastern region and the rest of the U.S. and Canada is projected to grow significantly in upcoming decades. From a climate perspective, the best way to maximize efficiency in this sector is to shift as much freight movement as possible to transportation modes that are more efficient than trucking. The business-as-usual projection by the Federal Highway Administration assumes that throughout the U.S., the relative shares of truck to train freight traffic will stay constant.

Figure 2.20: Rail and Truck Freight Tonnage, 2000 and 2020[107]



Source: Freight Rail White Paper I-95 Intermodal Leadership Forum

However, the congestion, extensive road wear and air pollution problems particular to the southern New England states and the opportunity to promote new transportation connections to the mid-Atlantic and Eastern Canadian regions may drive a different outcome, if forward-thinking policy is embraced.

The I-95 Corridor Coalition is in the process of developing a regional transportation profile of the Northeast Region (including the New England states plus New York). The Northeast Rail Operations (NEROps) Study will determine key trends and issues affecting rail transport in the region, including:[108]

- current and future demand for rail transport;
- anticipated rail improvement projects/activities;
- the interface between the NEROps region, the Mid-Atlantic Region, and the Eastern Canadian Provinces;
- identification of key regional chokepoints (physical, operational, informational, institutional).

The NEROps Study will contain a proposed regional rail improvement program.

---

107 Freight Rail White Paper I-95 Intermodal Leadership Forum. Figure 1 p. 2. Data from FHWA Freight Analysis Framework.
http://www.i95coalition.org/PDF/Meetings/ITPG/intermodal%20forum/Paper%20Freight%20Rail.pdf
108 I-95 Corridor Coalition, *Northeast Rail Operations (NEROps) Study*, Briefing Book, May 2005.

Implementation

We recommend that the I-95 Corridor Coalition consider expanding the scope of the study to include opportunities to expand waterborne commerce in the region. The results and recommendations of the NEROps Study should be implemented with a goal of shifting 10% of truck ton-miles to rail and waterborne modes by 2015.

The goal here is initially modest, because there are major economic, political and infrastructural hurdles to overcome. However, through a concerted public-private effort to improve inter-modal shipments and connections in this region, significant freight transport efficiency can be gained in the medium term.

Summary of Transportation Recommendations – GHG Benefits

Transportation system emissions, like other sectors of the economy, are driven by multiple factors. Of the policies discussed, all interact with each other to influence total emissions. The key drivers and policy frameworks that impact Transportation emissions are:

- Net GHG fuel emissions standards
- GHG Vehicle emissions per mile (California GHG emission standards for vehicles)
- Vehicle energy use per mile (CAFE standards)
- Vehicle miles traveled (VMT policies)
- Non-GHG emissions (reducing black carbon aerosols from heavy diesel vehicles)

Over the longer term and by mid-century, contributions from all of the transportation policy elements recommended in this Transportation Chapter will be required in order to achieve the 75% to 85% emissions reduction goal. The growth in vehicle miles traveled will have to be eliminated and emissions per mile will have to be reduced through a combination of new technologies, improvements in vehicle efficiency, and lower net GHG content fuels. Mid-century targets for various sub-sectors addressed in this chapter include:

Table 2.17: GHG Emissions Reduction Estimates for Transportation Policies by 2020

Net GHG Fuels Standard	3 to 4 Million Metric Tons CO_2e
Pavley Vehicle Emissions Standards	16 Million Metric Tons CO_2e
CAFÉ, Vehicle Efficiency Standards	Unable to Quantify
Policies to Reduce VMT	Unable to Quantify
Black Carbon Reduction from Heavy Vehicles	4 Million Metric Tons CO_2e
Efficiency Improvements from Freight	Unable to Quantify

The other policy proposals related to incentives, research, and planning will likely be critical to achieving the deep reductions in emissions required for the transportation sector and support these four drivers and policies.

The overall target for the transportation sector should be a 75-85% reduction by mid-century. The policies proposed for transportation in this report are estimated to deliver emissions reductions of the following magnitude by 2020 if implemented by all states and provinces in the region. (Note that there is significant interaction between the policies.)

Table 2.18: GHG Emissions Reduction Targets for Transportation Policies by 2050

Net GHG Fuels Standard	75% Reduction in Net GHG Content for all Fuels
Pavley Vehicle Emissions Standards	75% Reduction GHG Emissions per Mile
CAFÉ, Vehicle Efficiency Standards	50% Increase in Vehicle Energy Efficiency per Mile
Policies to Reduce VMT	Reduce Growth in VMT and Hold VMT Constant