Transportation and greenhouse gas mitigation

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Transportation presents a substantial and growing worldwide greenhouse gas (GHG) emission challenge. GHG mitigation strategies can be grouped into three categories: vehicle efficiency, low carbon fuels, and travel reduction. Potential GHG reductions are very large, with varying levels of cost effectiveness. Virtually all provide large co-benefits, including energy cost savings, oil security, and pollution reduction.

TRANSPORTATION SECTOR CHALLENGES

Transportation accounts for about one-fifth of total greenhouse gas (GHG) emissions worldwide, but close to 30 per cent in most industrialised countries. Worldwide, transport GHG emissions are growing faster than those from any other sector. Most are associated with motor vehicles, but air transport is an increasingly important source. Studies of cost effectiveness generally find transportation GHG reductions more expensive than reductions in most other sectors. The high cost is due to: low fuel price elasticity by passenger car owners (and light trucks); strong demand for personal travel, air travel, and goods transport; the difficulty of introducing new low carbon fuels and new fuel efficient propulsion technologies; deteriorating quality of public transport virtually everywhere; and the increasing share of goods carried by truck. In addition, petroleum fuel use is becoming more carbon intense. As easily accessed and high quality reserves are depleted, more carbon intense and remote sources of fossil energy are tapped and additional refining is required to upgrade fuel quality.

The analysis here focuses on the two largest components of the transportation sector: passenger automobiles and commercial freight trucks. Together, these make up about two-thirds of transportation GHG emissions.

GREENHOUSE GAS STRATEGIES

Despite analyses that indicate transportation options tend to be less cost effective than others, there are many reasons why these are misleading. First, there are large, highly valued co-benefits. Most strategies to reduce transport GHG emissions also reduce petroleum use, thereby contributing to energy security. Most also reduce emissions of local conventional pollutants and those that involve reduced vehicle use also reduce traffic congestion. Second, many incremental, low cost technologies exist to reduce energy use. Innovations in engines, transmissions, aerodynamics and lightweight materials have continuously yielded greater efficiency. Many additional fuel saving innovations are being pursued. Third, the automotive industry has become highly competitive, with companies seeking ways to distinguish themselves. The halo created by the successful Prius hybrid has proved extraordinarily valuable to Toyota. It has shown that being first has great value. Toyota increased the value of its brand and the attractiveness of its other vehicles far more effectively than advertising. Companies are now increasing their investment in a wide variety of new low carbon fuels and efficient advanced propulsion technologies to achieve the same halo benefits. Fourth, there is substantial evidence that reductions in vehicle use are desirable and attainable for a wide variety of reasons. And fifth, there are many policies that could reduce fuel consumption and GHG emissions at zero net cost for the simple reasons that consumers do not highly value, or are unaware of, efficiency considerations in their vehicle purchase decision and ignore many simple practices to reduce fuel use.

VEHICLE EFFICIENCY

Available and emerging vehicle efficiency improvements can be categorised into three groups.

Incremental vehicle technologies

Incremental improvements include more efficient combustion, such as variable valve systems, gasoline direct injection, cylinder deactivation, more efficient transmissions such as 5- and 6-speed automatic, automated manual and continuously variable, and overall vehicle advances, such as aerodynamics and light-weighting. Greenhouse gas emissions rates can be reduced by 20-30 per cent with these technologies in new vehicles. Most studies show that fuel savings from these improvements more than outweigh the increased vehicle cost, often by a large amount. Similar technology packages yield substantial GHG reductions and net positive benefits for commercial freight trucks as well.

Advanced technologies

Much greater GHG reductions are possible with electric drive propulsion technologies. These include the increasingly popular hybrid gasoline-electric vehicles, plug-in hybrids which use both electricity and petroleum fuels, battery electric vehicles and hydrogen powered fuel cell vehicles. Such technologies can double vehicle fuel efficiency. The life cycle GHG emissions, considering the potential to use low carbon electricity and hydrogen, can be reduced by at least 80 per cent. However, these advanced technologies involve either larger initial costs, for electricity and hydrogen storage, and/or have high development costs and uncertain learned-out costs. Because vehicle turnover is slow and it takes a long time to deploy a new energy distribution system, it will take a long time to realise potential reductions.

On-road operational practices

On-road efficiency improvements involve a combination of consumer education, vehicle maintenance practices, and off-cycle vehicle technologies. Improvements to on-road vehicle efficiency can reduce GHG emissions by up to 20 per cent. Improved vehicle maintenance practices with regard to tires, wheels, oil and air filters ensure vehicles operate as efficiently as they were designed to do. Technologies in new vehicles that aid driver awareness of fuel use include dashboard instruments that present instantaneous fuel consumption, efficient engine rpm ranges, shift indicator lights, and tire inflation pressure.

There are many possible policies to bring about these vehicle improvements. In addition to education and informational initiatives, incremental vehicle efficiency can be achieved with performance standards aimed at automakers, vehicle purchase and use taxes aimed at consumers and vehicle suppliers, and various actions aimed at assuring the supply of alternative fuels for the advanced vehicles. To make sure deeper GHG cuts in future years are achieved, government tax incentives to industry and consumers will be needed to overcome initial cost, institutional and infrastructure concerns and barriers.

LOW CARBON FUELS

Increased use of low carbon fuels, or fuels with lower life cycle GHGs, can greatly reduce overall transportation GHG emissions. Most alternative transportation fuels face a combination of infrastructural and economic barriers. The easiest action is to blend small proportions of biofuels into gasoline and diesel fuel. Biofuels are not necessarily less expensive, but the processes for converting abundant agricultural feedstocks, such as corn and sugarcane, into ethanol are well known and ethanol is easily blended into gasoline for use in conventional vehicles. The GHG benefits of sugarcane conversion are substantial, compared to gasoline, but only about 10-20 per cent for corn. Future biofuels, made from agricultural residue or cellulosic energy crops could have life cycle GHG benefits of 90-100 per cent. A similar array of biofuel feedstocks can be used to produce biodiesel, which can be mixed into conventional diesel fuel.

There are also other transport fuel options systems involving wholly different fuels and fuel distribution systems that can greatly impact GHG emissions. Marginally lower GHG fossil fuels, such as compressed natural gas and liquefied petroleum gas have continued to make small contributions to transportation, mostly in fleet vehicles. On the other hand, next generation fossil fuels produced from oil shale, coal, and tar sands would have much higher GHG emissions than conventional petroleum, unless the carbon from such fuels was captured and stored underground.

Large potential GHG benefits can be achieved by powering vehicles with hydrogen (and fuel cells) and electricity, with plug-in hybrids and battery electrics. Electric drive vehicles, powered by low carbon versions of these fuels made with biomass, wind, nuclear energy, or with fossil energy coupled with carbon capture and storage, could yield much greater GHG reductions than with vehicle efficiency improvements alone.

Lower carbon fuels have been subsidised and mandated by various governments, including biofuel mandates in Europe and ethanol subsidies in the US and Brazil. A new policy instrument gaining much attention worldwide is the low carbon fuel standard. In this case, government does not pick winners. It sets a greenhouse gas intensity target, eg 10 per cent reduction by 2020, and allows companies to meet the requirement however best suits them. Or companies can buy credits from those exceeding the GHG target.

Table: Summary of transportation greenhouse gas mitigation options and policies.

Category	Today's measures (deployable 2007-2015)	Tomorrow's measures (deployable 2010-2030)	Supporting policies and practices
Vehicle efficiency	• Incremental efficiencyimprovements in conventional asoline automobiles and diesel trucks. • "On-road" improvements in maintenance practices, technology, driver education and awareness.	• Increased vehicle electrification (hybrid gas-electric, plug-in hybrid, battery electric). • Fuel cell vehicles.	• Vehicle efficiency performance standards (fuel economy, CO2 emission rate). • Voluntary industry commitments. • Vehicle purchasing incentives (rebates, feebates for low CO2, high fuel economy). • Government and company fleet efficient vehicle purchasing.
Low greenhouse gas fuels	• Mixing of biofuels in petroleum fuels. • Use of lower GHG content fossil fuels (eg diesel, compressed natural gas).	• Electricity (in plug-in hybrids and battery electrics). • Cellulosic ethanol. • Hydrogen from renewable sources. • Mobile air-conditioning (MAC) refrigerant replacement.	• Biofuel blending mandates. • Low GHG fuel standards. • Carbon tax on fuels. • Government and company fleet incorporation of alternative fuels.
Vehicle demand reduction	• Intelligent transportation system (ITS) technologies to improve system efficiencies. • Mobility management technologies. • Inclusion of GHG impacts in land use and transport planning. • Incentives and rules to reduce vehicle use.	• Greenhouse gas budgets for households and localities. • Modal shifts (road to rail freight, public transit systems). • ITS technologies to create more efficient transport modes.	• Road, parking, congestion pricing. • Investment in public transit. • Public awareness, outreach, education campaigns.

TRAVEL REDUCTION

The same technologies and practices implemented by local governments to manage vehicle travel and traffic congestion can also be used to reduce GHG emissions. Strategies to reduce vehicle travel can be sorted into three broad groups. Information and communication technologies

Information and communication technologies can be used to improve mobility and reduce transport GHG emissions. Incremental enhancements include: automating urban traffic signals to streamline traffic and reduce stop and go conditions; implementing integrated smart cards to facilitate multimodal travel and increase transit use; provide real time traffic data to traffic managers and vehicle users to improve efficiency. More substantial changes are possible by creating entirely new modes of travel, such as smart car sharing that allows convenient short term rentals, smart paratransit that provides door to door service without advanced reservations, and dynamic ride sharing that facilitates organised ride sharing.

Incentives and pricing schemes

Various incentive and pricing schemes can be designed to reduce GHG travel. Road pricing for city centres or highway congestion can moderate traffic and reduce GHG intensive travel. Parking policies, such as park and ride near transit facilities and parking cash-out programmes by employers, encourage higher occupancy travel modes. Incentives by workplaces to promote telecommuting and carpooling can also help mitigate peak time congestion travel. Vehicle pricing in conjunction with improved transit service programmes, such as bus rapid transit, attracts travellers to higher occupancy and thus lower GHG modes.

Denser land use

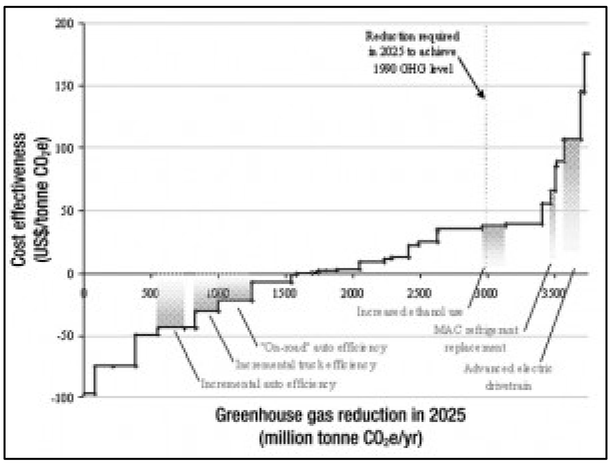
Densification of land use may be the most effective way to reduce the use of GHG intensive modes of travel. Research shows that residents in more densely populated areas and in areas with better mixes of land uses tend to emit far less GHG emissions from their travel. They tend to walk more, use public transportation more and drive less. Policies aimed at increasing density and influencing local governments to make land use development and zoning decisions based on likely impact on GHG emissions, could be highly effective at reducing emissions.

SUMMARY OF TRANSPORTATION GHG STRATEGIES

The Table above categorises transportation sector GHG mitigation options into near and mid term options. For the near term, or ‘Today’s measures,’ options highlighted are currently available and easily applied but would require policies or shifts in practice to achieve widespread adoption. For ‘Tomorrow’s measures,’ the listed strategies offer deeper possible emission cuts, but there is greater uncertainty in how technology costs will drop over time and how industry will act.

GREENHOUSE GAS MITIGATION SUPPLY CURVES

Greenhouse gas mitigation strategies can be ranked using a supply curve framework. They are ranked according to their GHG reduction cost effectiveness, or cost per tonne of CO2 equivalent emission reduction. Both the initial costs of the GHG technologies and the lifetime energy savings are included in the cost per tonne metric. The Figure is a supply curve of GHG mitigation actions for all sectors of the US economy, with transportation-specific measures highlighted (data from Lutsey, 2007). The non-transportation actions include electric power sector actions, eg coal to natural gas shift, carbon capture and sequestration, increased nuclear power, renewable electricity, more energy efficient buildings, including improvements in appliances, lighting, and air conditioning, and hydrofluorocarbon emission reduction technologies.



CONCLUSION

Many transportation strategies to reduce GHG emissions are highly cost-effective. Many generate cost savings over the life of an investment (in a particular energy-saving technology or product), when future energy savings are calculated using normal discount factors. When other co-benefits are included, such as improved energy security, many transport GHG mitigation options become attractive. These findings are counter to the conventional wisdom that often ignore co-benefits and emphasise near term resistance to the broad suite of technology and behavioural options.

Policies to bring low GHG technologies and practices to widespread deployment have already emerged and proven successful in limited venues. The available policy strategies are diverse, including local policies that integrate transport and land use decisions, fuel efficiency and GHG performance standards on vehicles, outreach and incentive campaigns to instil energy saving attributes into all consumer decisions and government and corporate research that promote technological breakthroughs and reduce infrastructural and implementation cost barriers.

Authors

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Organisation

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