Vehicles and Fuels

Transportation Workshop
for Minnesota Legislators
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Land Use and System Shifts

$$E = F \text{ x } C \text{ x } A$$

$$\text{Emissions} = \underbrace{\left(\frac{\text{Gallons}}{\text{Mile}}\right)}_{\text{Fuel Consumption}} \times \underbrace{\left(\frac{\text{Carbon}}{\text{Gallon}}\right)}_{\text{Carbon Content}} \times \underbrace{\left(\begin{matrix}\text{Vehicle Miles}\\ \text{Traveled}\end{matrix}\right)}_{\text{Activity}}$$

Vehicles and Fuels
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- New CAFE was adopted and implementation accelerated during course of study
- CA standards are more aggressive than Federal
- Recent MIT study indicates that if 1987 vehicle size and performance were combined with 2006 driveline technology, fuel consumption would be reduced by 30% - this is a greater reduction than targeted by CAFE and essentially equal to the CA target

Background

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Strategies: Vehicle Efficiency

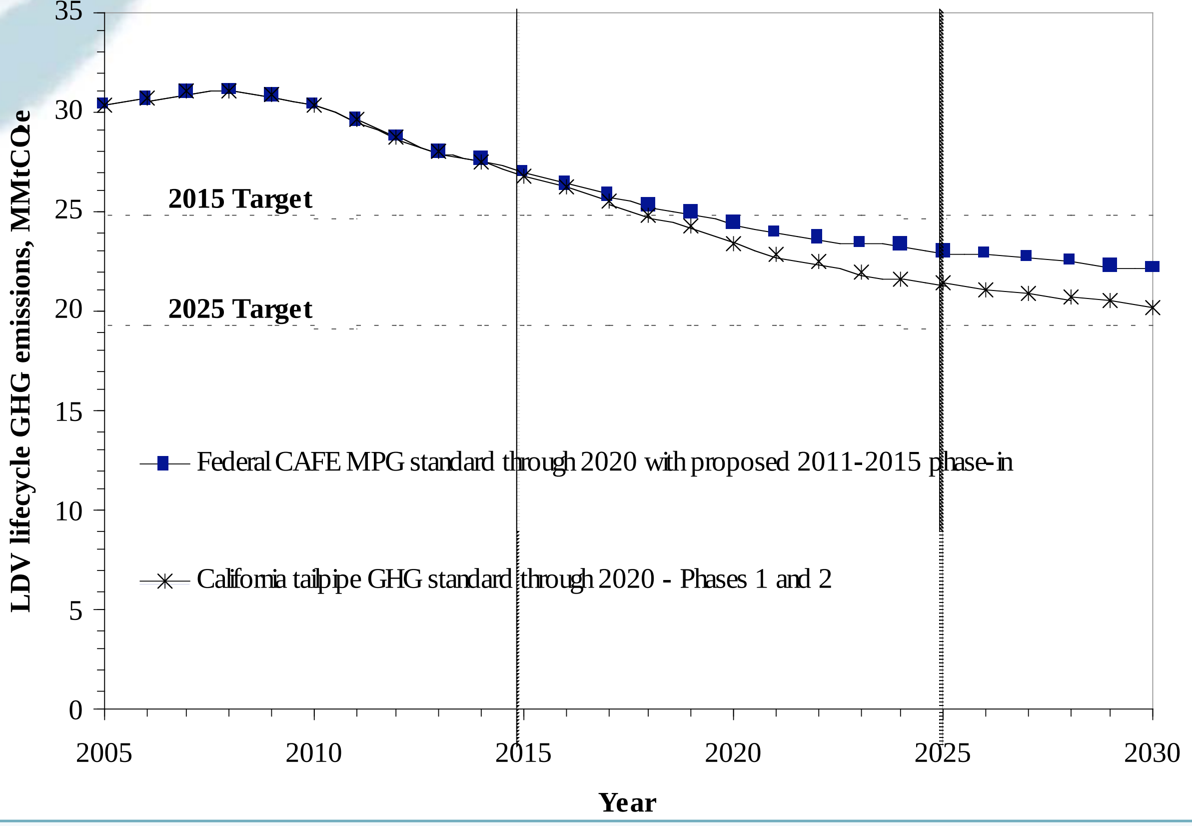
- **Light duty on-road vehicles (LDVs)**
  - Federal CAFE new vehicle MPG standard
  - California tailpipe new vehicle GHG emissions standards
  - Economic incentives for more efficient vehicles: fees and rebates
  - Driver education
  - Many options for improving vehicle efficiency are available

- **Heavy duty on-road vehicles (HDVs)**
  - More efficient diesel engines
  - Other efficiency improvements (e.g., tires, aerodynamics)
  - Driving behavior and idle reduction

- **Airplanes, trains and ships**
  - High jet fuel price incentive for efficient aircraft
  - Trains and ships benefit from diesel efficiency technologies developed for on-road HDVs

Proposed U.S. and International Light Duty Vehicle Efficiency Standards

- California and CAFE produce similar GHG reductions up to ~2015
- California produces larger reductions later
- Fuel savings rapidly offset higher cost of more efficient vehicle
- Many other major countries have more aggressive efficiency improvement goals: technology to achieve these goals exists



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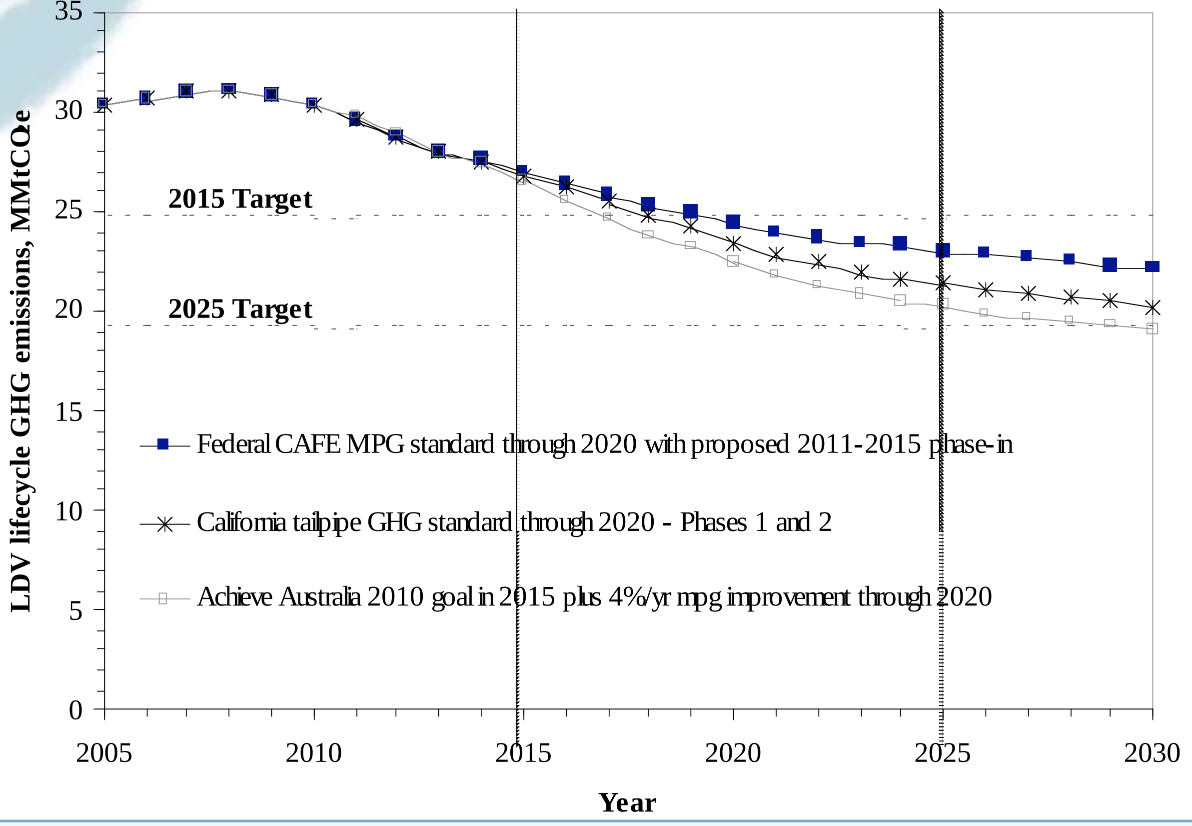

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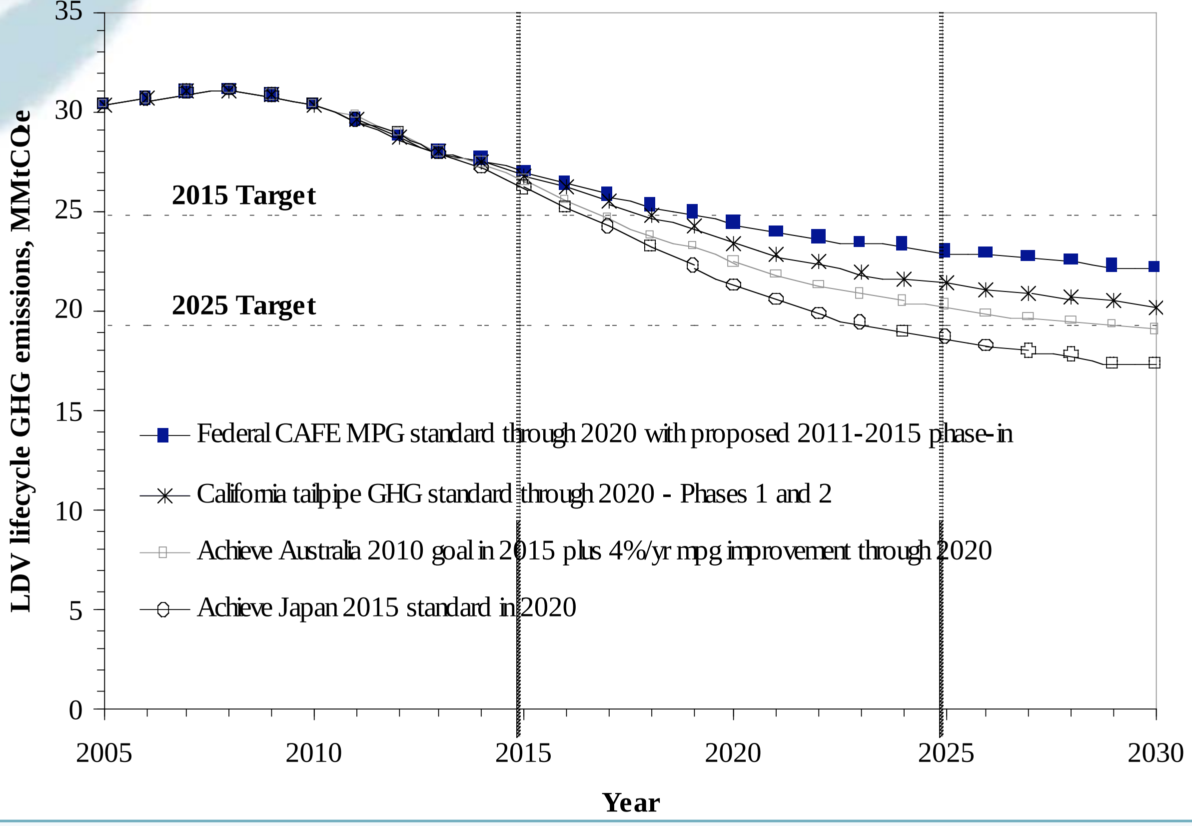


Economic Incentives for More Efficient Light Duty Vehicles

- Fees on inefficient vehicles and rebates for efficient vehicles ("feebates")
  - can produce emissions reductions comparable to mandated standards
  - can be combined with standards to produce greater reductions than either strategy alone

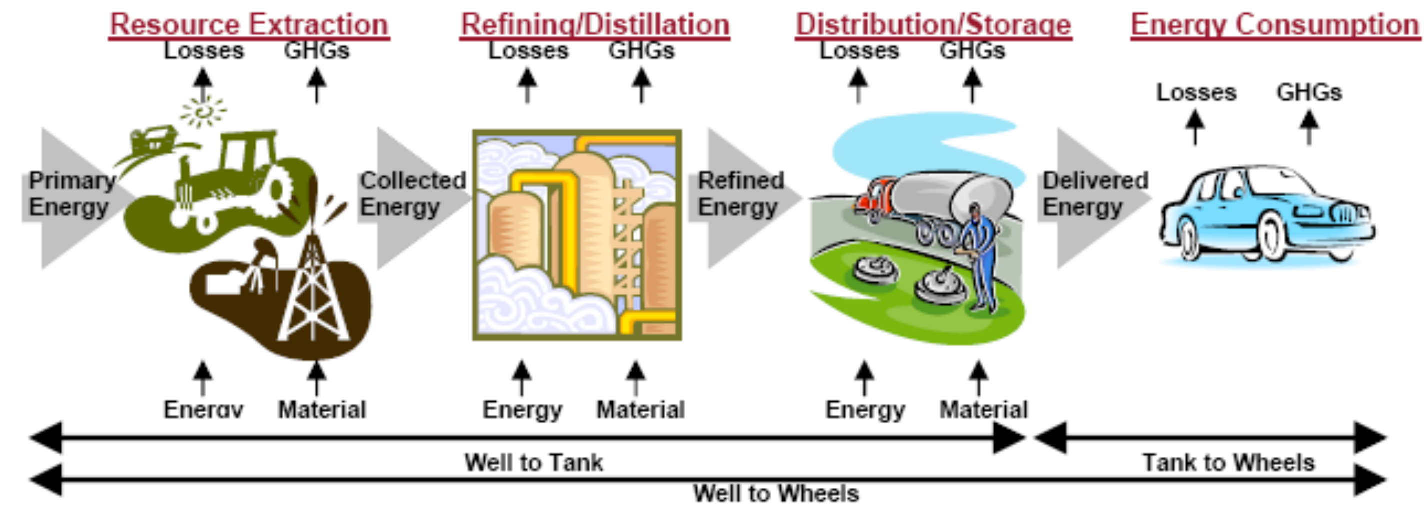
- Policy should be enacted with other states to leverage influence on vehicle makers' decisions

- Real world case study: high fuel prices

Heavy Duty Vehicle Efficiency Improvements

- Improvements
  - Idle reduction (auto idle off, on board generators, plug-ins)
  - Speed reduction
  - Aerodynamic upgrades – tractor and trailer
  - Wide-based tires
  - Low-friction lubricants
  - Driver training and monitoring
  - Tire auto inflation
- Combined, improvements can contribute 10 – 16% of 2015 and 2025 transportation GHG reduction goals
- EPA's SmartWay program
  - Low interest loans to upgrade HDV efficiency
  - Minnesota has strong participation
  - State could provide further incentives to increase participation by MN-based truckers
- Similar technology improvements and behavior changes can be applied to light duty vehicles

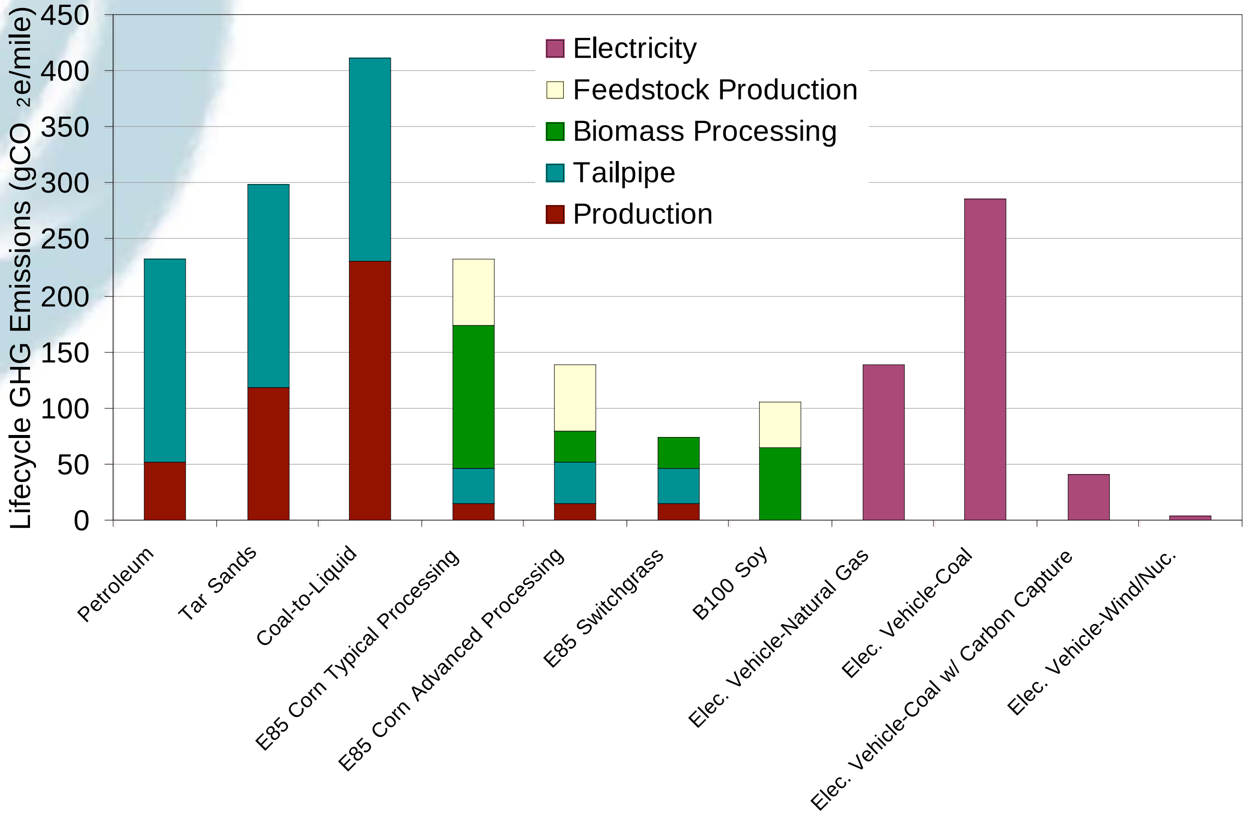
Strategies: Fuel Carbon Content



- Fuel carbon content must be calculated on a lifecycle basis
  - No standardized methods
  - Land use changes not well understood (e.g., converting virgin land to crop land)

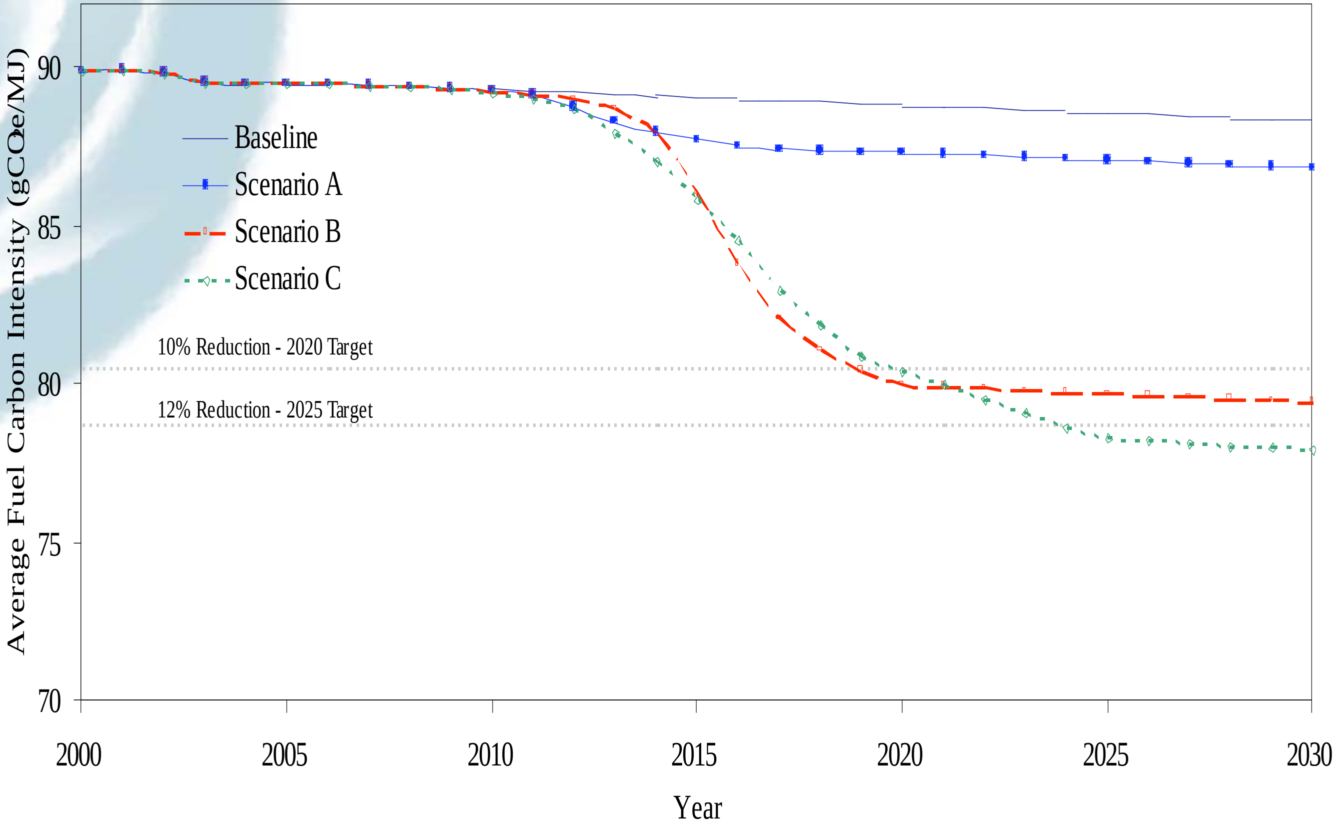
- To reduce carbon fuel content over the long-term requires
  - Feedstocks other than corn
  - Improved production methods

Fuel Lifecycle GHG Emissions



- **The same fuel can have a variety of emissions based on production pathway and feedstock**

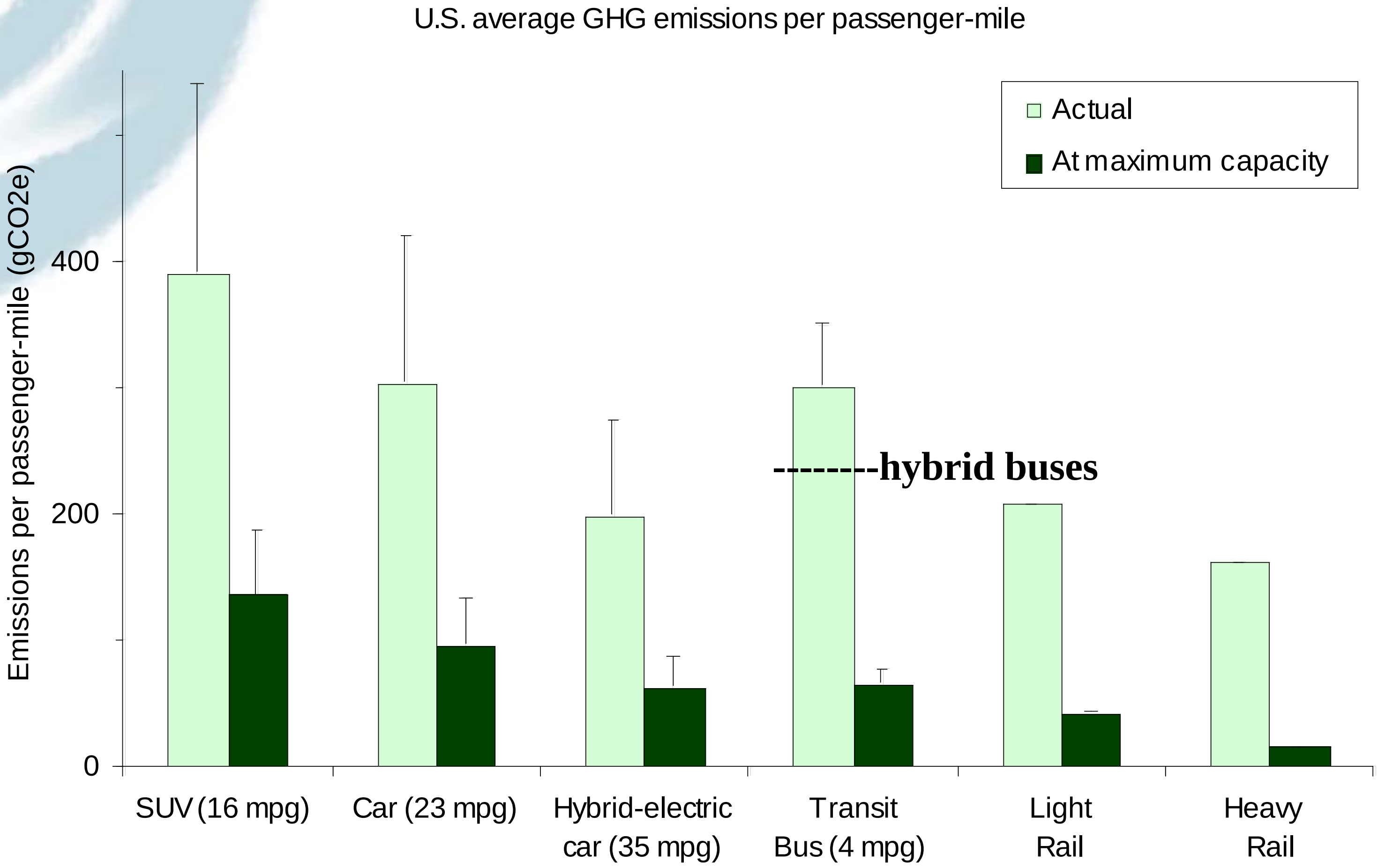
Emissions Reductions from Low Carbon Fuels



Baseline: E10 mandate
Scenario A: E20 mandate, no advancement in ethanol processing
Scenario B: E20 mandate, all ethanol produced by stover-fired dry mill process
Scenario C: E10 mandate, all ethanol from cellulosic sources

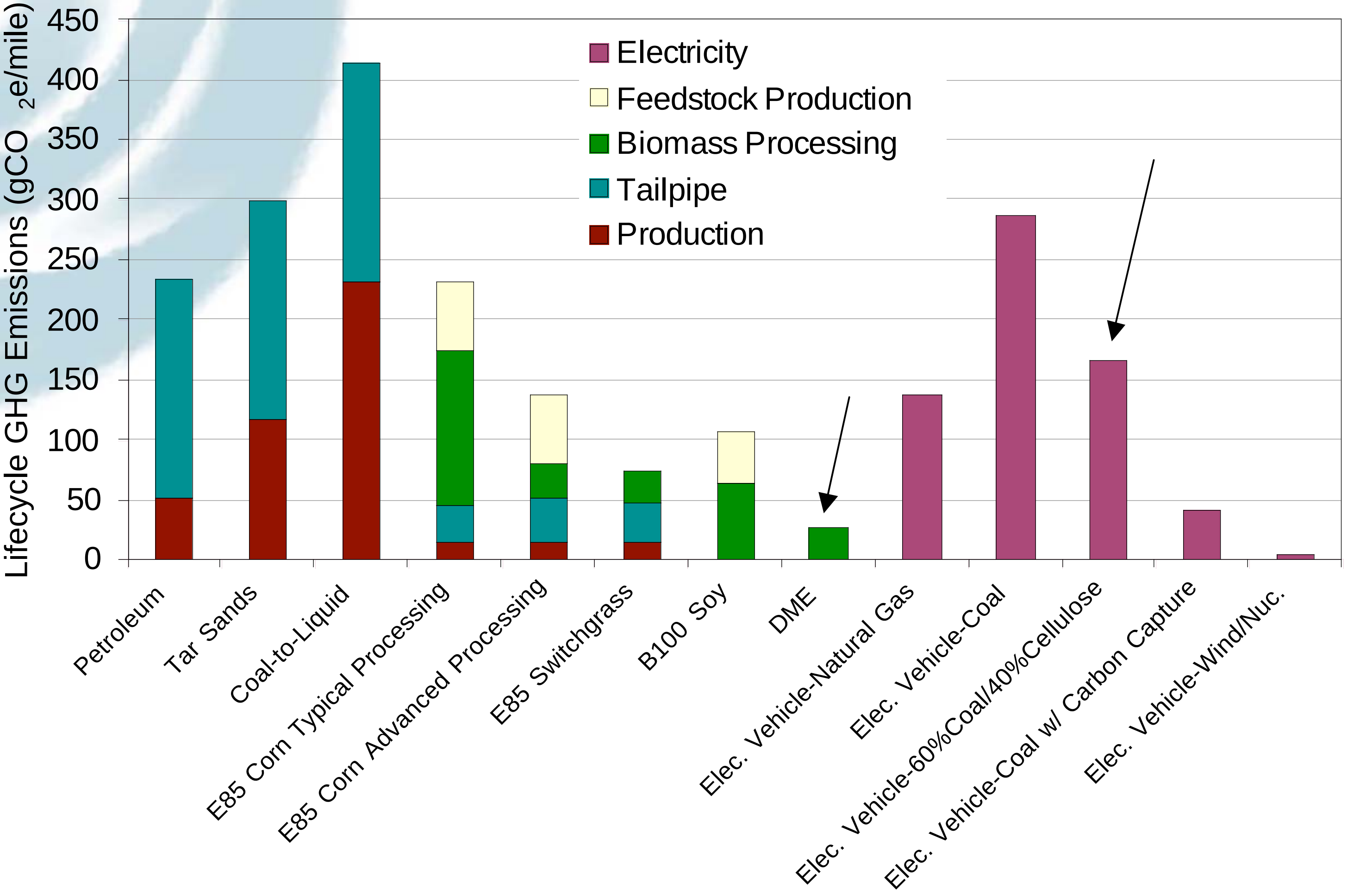
Additional Charts
for Purposes Q & A

GHG Emissions By Travel Mode - Average Emissions


U.S. average GHG emissions per passenger-mile

--------hybrid buses

Fuel Lifecycle GHG Emissions



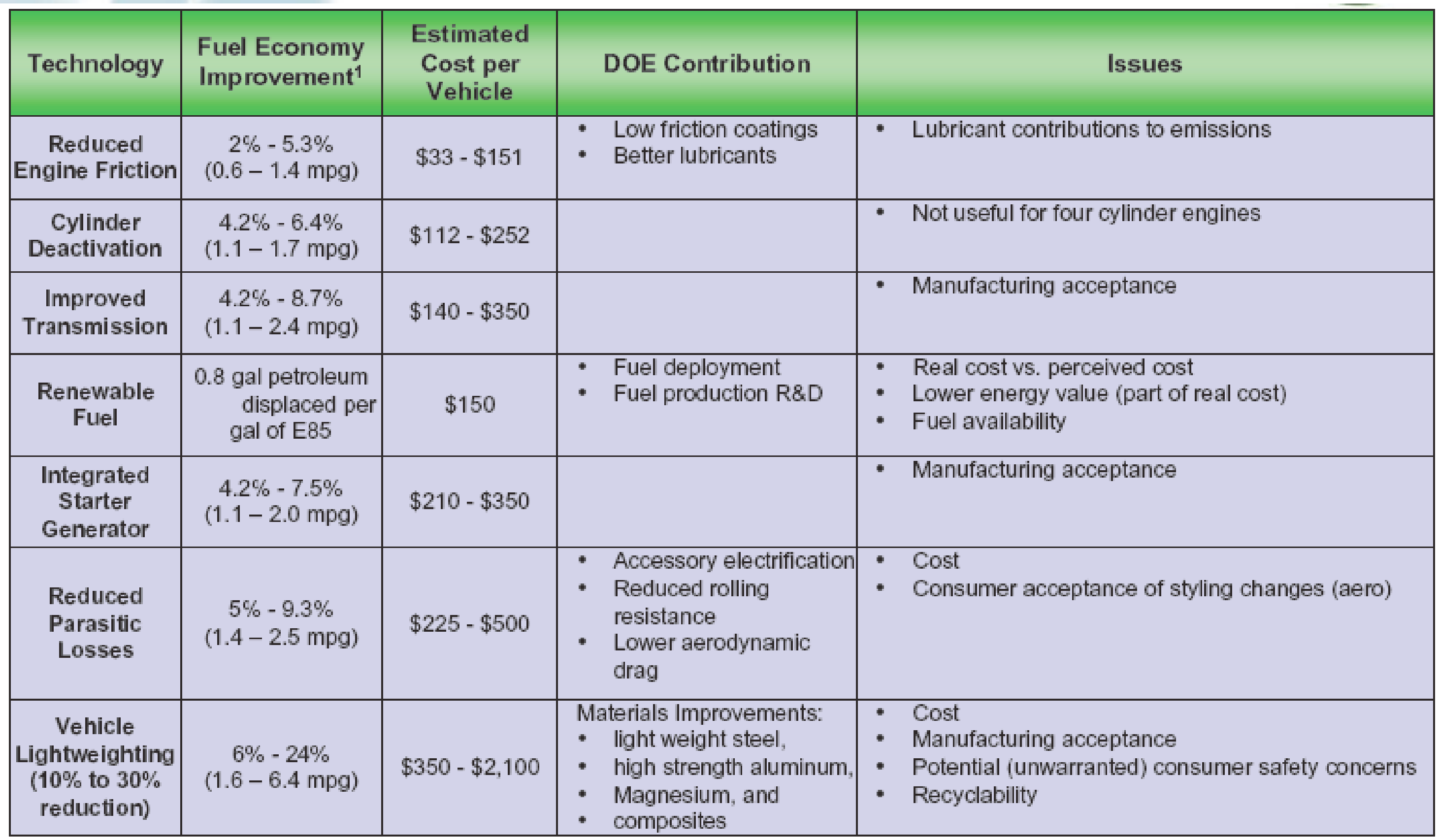
Promising Technologies and Strategies for 2050 Reduction Goal

- Electric and hybrid electric plug-in vehicles -- require charging by cleaner electricity
- Freight mode switching
- Second generation biofuels
- Land use and system shifts

Conclusions

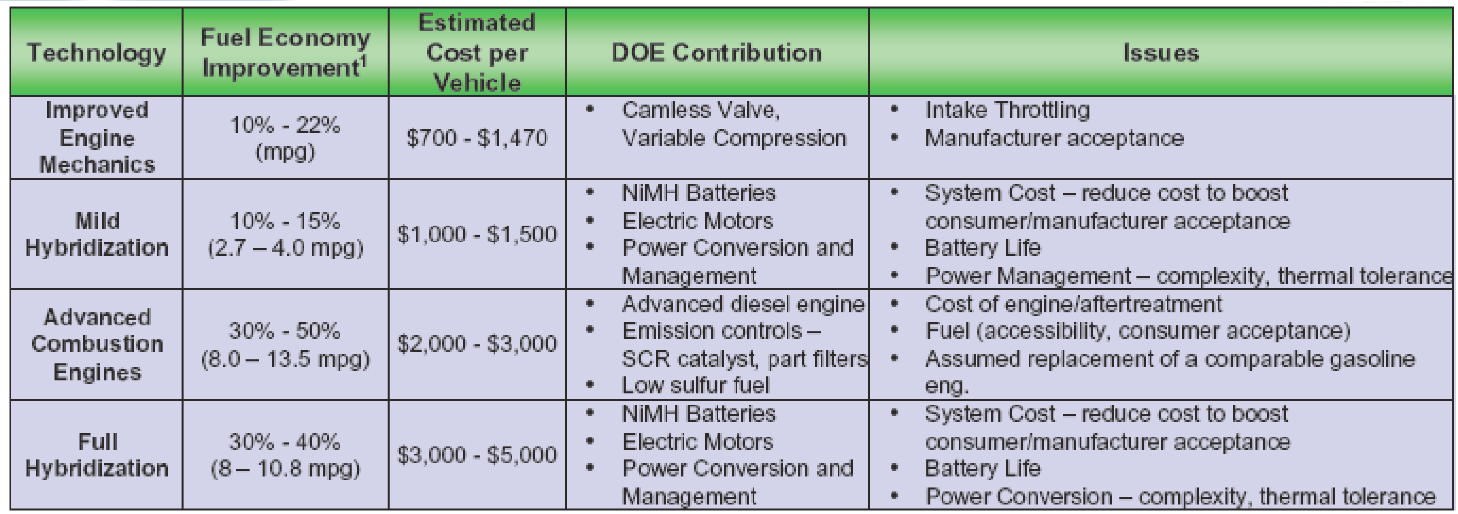
- **2015 and 2025 transportation GHG reduction goals are technologically achievable**
  - Strategy combinations: reduce fuel consumption, VMT and fuel carbon content
  - Fuel economy standards more stringent than either CAFE or California are possible with available technology. Other nations have set more aggressive goals.
  - Policies such as low carbon fuel standard and vehicle efficiency/emissions standards are most effective when implemented with other states
- **Lifecycle (well- or field-to-wheels) analysis is necessary to assess transportation GHG strategies**
  - Electricity generation must be clean to realize overall reductions from electric vehicles
  - Production methods and land-use impacts of biofuels must be considered
- **Fuel efficiency improvements clearly benefit the Minnesota consumer**
  - Studies elsewhere show overall economic benefits for GHG reduction policies
- **VMT reduction requires understanding connection between land use and transportation**

Vehicle Efficiency Technology



Technology	Fuel Economy Improvement^1	Estimated Cost per Vehicle	DOE Contribution	Issues
Reduced Engine Friction	2% - 5.3% (0.6 – 1.4 mpg)	$33 - $151	• Low friction coatings • Better lubricants	• Lubricant contributions to emissions
Cylinder Deactivation	4.2% - 6.4% (1.1 – 1.7 mpg)	$112 - $252		• Not useful for four cylinder engines
Improved Transmission	4.2% - 8.7% (1.1 – 2.4 mpg)	$140 - $350		• Manufacturing acceptance
Renewable Fuel	0.8 gal petroleum displaced per gal of E85	$150	• Fuel deployment • Fuel production R&D	• Real cost vs. perceived cost • Lower energy value (part of real cost) • Fuel availability
Integrated Starter Generator	4.2% - 7.5% (1.1 – 2.0 mpg)	$210 - $350		• Manufacturing acceptance
Reduced Parasitic Losses	5% - 9.3% (1.4 – 2.5 mpg)	$225 - $500	• Accessory electrification • Reduced rolling resistance • Lower aerodynamic drag	• Cost • Consumer acceptance of styling changes (aero)
Vehicle Lightweighting (10% to 30% reduction)	6% - 24% (1.6 – 6.4 mpg)	$350 - $2,100	Materials Improvements: • light weight steel, • high strength aluminum, • Magnesium, and • composites	• Cost • Manufacturing acceptance • Potential (unwarranted) consumer safety concerns • Recyclability

Vehicle Efficiency Technology



Technology	Fuel Economy Improvement[1]	Estimated Cost per Vehicle	DOE Contribution	Issues
Improved Engine Mechanics	10% - 22% (mpg)	$700 - $1,470	• Camless Valve, Variable Compression	• Intake Throttling • Manufacturer acceptance
Mild Hybridization	10% - 15% (2.7 – 4.0 mpg)	$1,000 - $1,500	• NiMH Batteries • Electric Motors • Power Conversion and Management	• System Cost – reduce cost to boost consumer/manufacturer acceptance • Battery Life • Power Management – complexity, thermal tolerance
Advanced Combustion Engines	30% - 50% (8.0 – 13.5 mpg)	$2,000 - $3,000	• Advanced diesel engine • Emission controls – SCR catalyst, part filters • Low sulfur fuel	• Cost of engine/aftertreatment • Fuel (accessibility, consumer acceptance) • Assumed replacement of a comparable gasoline eng.
Full Hybridization	30% - 40% (8 – 10.8 mpg)	$3,000 - $5,000	• NiMH Batteries • Electric Motors • Power Conversion and Management	• System Cost – reduce cost to boost consumer/manufacturer acceptance • Battery Life • Power Conversion – complexity, thermal tolerance

Payback on Efficient Vehicle

	Added cost of vehicle, $100		Added cost of vehicle, $500		Added cost of vehicle, $1000	
Fuel Cost	**Payback Period**	**NPV 15 Yrs**	**Payback Period**	**NPV 15 Yrs**	**Payback Period**	**NPV 15 Yrs**
$3.00/gal	<1 year	$1,800	<3 years	$1,400	6 years	$900
$3.50/gal	<1 year	$2,100	<3 years	$1,700	5 years	$1,200
$4.00/gal	<1 year	$2,500	2 years	$2,100	<5 years	$1,600

Cost savings are for a 29.5 MPG vehicle relative to a 25.5 MPG vehicle, with purchase in 2012 with a 15-yr life, 5% discount rate, 3% annual inflation rate for gasoline, $25,000 vehicle cost with $5,000 down payment and 8.64% annual interest on the balance for 5 years. All dollar values current year (2008) dollars.

Comparison of International GHG Emissions Standards

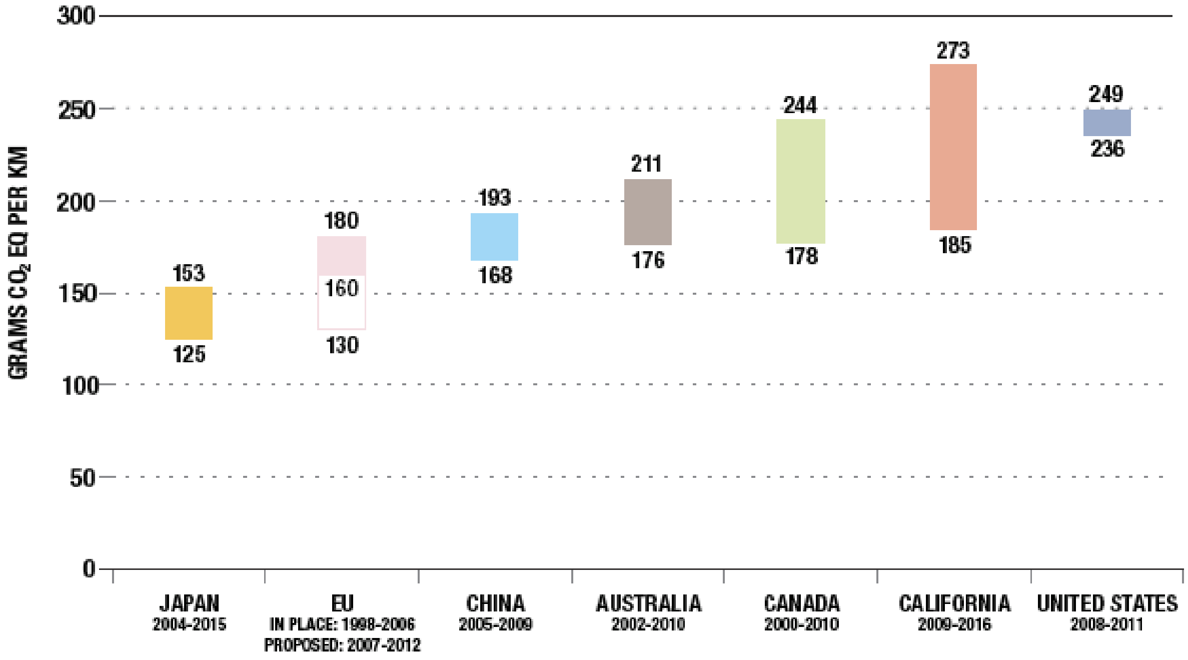
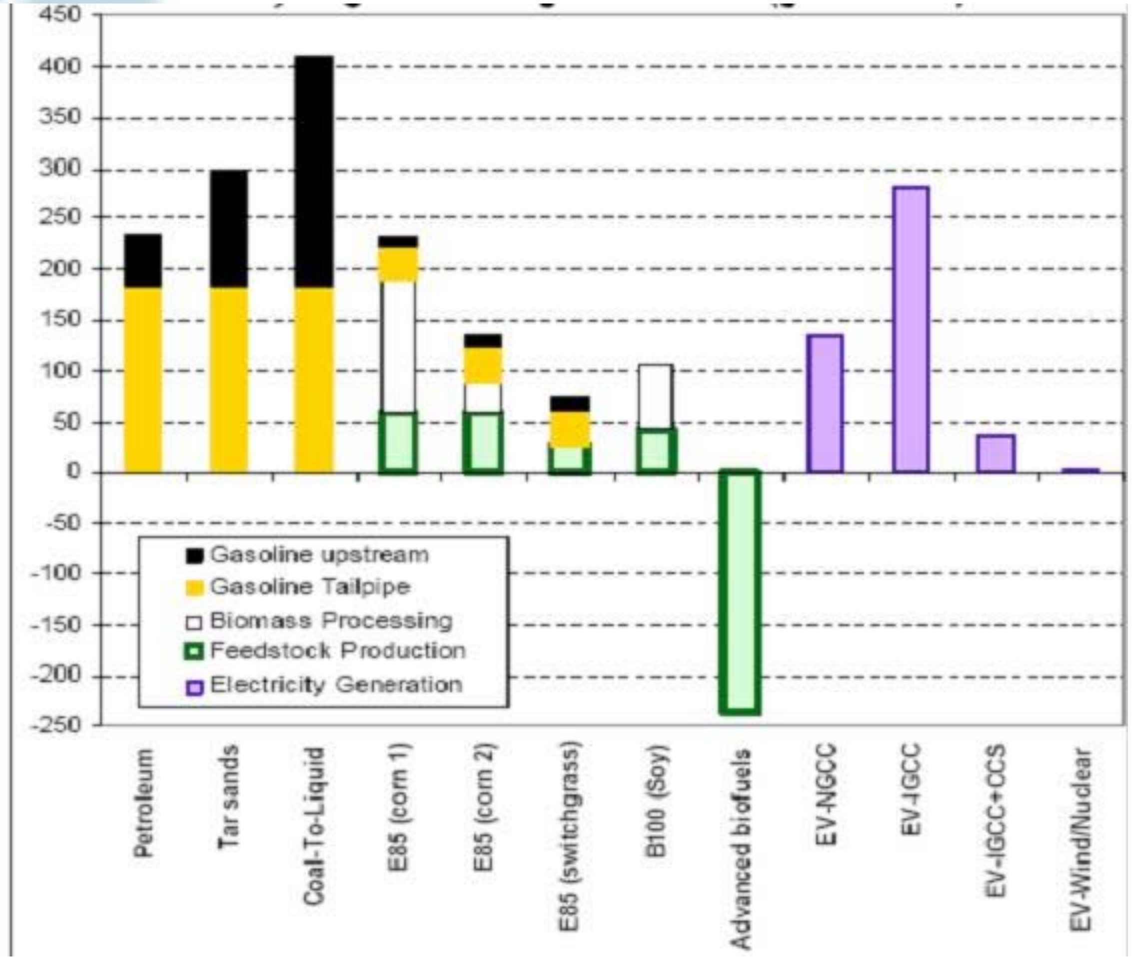


FIGURE 7. GHG Emission Reduction Associated with the Most Recent Regulations By Country

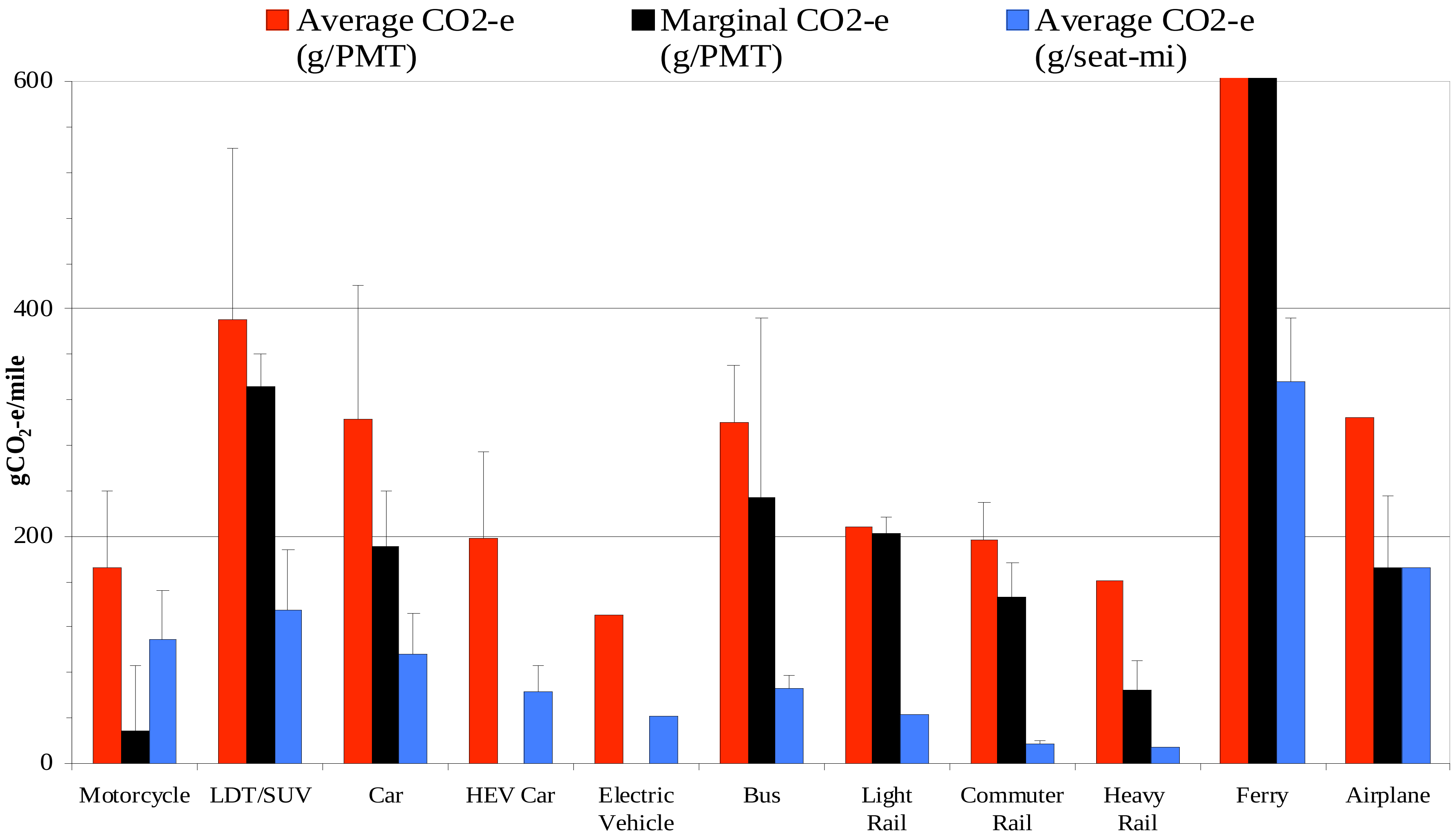
Note: Shaded bars denote in-place regulations; unshaded bars denote proposed regulations. Emissions data for Figure 7 are measured in grams CO_2-equivalent per kilometer under the NEDC test cycle. California and Canada's programs include reductions in non-tailpipe and non- CO_2 emissions.

An et al, 2007. Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update. International Council on Clean Transportation. Washington, DC www.theicct.org

Lifecycle GHG Emissions



GHG Emissions By Travel Mode- Average And Marginal Emissions



Background: Uncertainty Factors

- Future Federal regulations
- Estimates of carbon emissions from biofuels
- Future vehicle miles traveled (VMT) growth
- Impact of:
  - Fuel prices (oil/gasoline -- $200 barrel? $6/gallon?)
  - Crop prices
- Consumer response
- New technology developments

Transportation GHG Reduction Challenges

- Many small, mobile sources
- No exhaust aftertreatment technology to remove GHGs – i.e., no easy technical solution
- Negative health effects are diffused and delayed (global warming impacts)
- Transportation infrastructure development is expensive and slow
- Society's transportation-related choices are limited and preferences are difficult to shift rapidly
- Taxes and mandates are unpopular
- Markets are imperfect, limiting market-based solutions