Reducing Greenhouse Gas Emissions from Transportation Sources in Minnesota

A Study for the Minnesota Legislature

presented by

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Acknowledgements

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• We are very grateful for the technical assistance provided by:
  – Peter Ciborowski and others at the MN Pollution Control Agency
  – Frank Pafko and others at the MN Department of Transportation
  – Jan Homan and others at Metro Transit
Background: Transportation GHG Reduction Goals

• Reduction targets for total GHG emissions established by the 2007 Minnesota Next Generation Energy Act. Percent reductions referenced to 2005 total emissions:
  – 15% by 2015
  – 30% by 2025
  – 80% by 2050

• Study assumed transportation’s reduction target proportional to transportation’s share of total GHG emissions (~24%)
Study Findings

• Transportation sector can achieve its target

• Meeting the goals requires three approaches
  – More efficient vehicles
  – Low-carbon fuels
  – Land use and system change/VMT

• Must start now
Background:
Minnesota Transportation Sector
GHG Emissions

- On-road gasoline LDV: 2,503 Mgge
- On-road Diesel: 636 Mgge
- Aviation: 477 Mgge
- Other vehicles and fuels: 238 Mgge
- Railroad: 79 Mgge
- Marine: 40 Mgge

Millions of gallons equivalent (Mgge) consumed
Analytical Framework

\[ E = F \times C \times A \]

Emission \( E \) can be calculated as the product of fuel consumption \( F \), carbon content \( C \), and activity \( A \):

\[
E = \left( \frac{\text{Gallons}}{\text{Mile}} \right) \times \left( \frac{\text{Carbon}}{\text{Gallon}} \right) \times \left( \frac{\text{Vehicle Miles}}{\text{Traveled}} \right)
\]

Fuel Consumption \( \frac{\text{Gallons}}{\text{Mile}} \)

Carbon Content \( \frac{\text{Carbon}}{\text{Gallon}} \)

Activity \( \frac{\text{Vehicle Miles}}{\text{Traveled}} \)
Strategies

• **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
  – 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

Vehicle Fuel Consumption

\[ E = F \times C \times A \]
Comparison: 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

![Graph showing GHG emissions and targets for different standards.](image.png)

- Federal CAFE MPG standard through 2020 with proposed 2011-2015 phase-in
- California tailpipe GHG standard through 2020 - Phases 1 and 2
- Achieve Australia 2010 goal in 2015 plus 4%/yr mpg improvement through 2020
- Achieve Japan 2015 standard in 2020
Vehicles and Fuels – Potential for Fuel Economy Improvements

• Recent MIT study on the potential for fuel economy improvements found:
  – Combining 1987 vehicle weight and acceleration with 2006 driveline technology would increase fuel economy by
    – 50% for cars - 33% reduction in fuel consumption
    – 45% for light trucks - 31% reduction in fuel consumption

• These are greater improvements than targeted by CAFE and even slightly greater than the CA target
Economic Incentives for More Efficient LDVs

- Efficiency standards produce consumer savings
  - Fuel use reductions offset technology costs
  - Payback 1 to 6 years (at time of study)
  - NPV $900 to $2500 (15 year vehicle life)

- Feebates: Fees on inefficient vehicles and rebates for efficient vehicles
  - Emissions reductions can be comparable to standards
  - Combine with standards for larger reductions

- Feebates should be enacted with other states to leverage influence on vehicle makers’ decisions

- Real world case study: high fuel prices (2007-2008)
Fuel Carbon Content

\[ E = F \times C \times A \]

- Carbon emissions must be evaluated on a total life cycle basis
- Changing fuel often changes vehicle fuel consumption as well, e.g., Diesel engines are about 20% more efficient than current gasoline engines. This is accounted for in well to wheel analysis.
• 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
• Current ethanol is no better than petroleum – cellulosic is the hope
• DME has the best footprint of any other portable fuel
• Electric vehicles with electricity from biomass or wind may be best for urban vehicles

Adapted from: Farrell and Sperling, 2007
Emissions Reductions from Low Carbon Fuels – Better Biofuels not more Biofuels

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 – Achieves Low Carbon Fuel Standard
Land Use and System Shifts

\[ E = F \times C \times A \]

• Understanding Reductions in VMT is more complex than fuel and vehicle changes.
  – Trip reduction
  – Mode shift
Minnesota VMT Trends: Historical and Projected

Vehicle miles traveled x 10^9

- Historic
- High Growth - 2.3%
- Medium Growth - 0.9%
- Low Growth - 0.0%

Year

Effect of VMT Growth Assumption on Emissions Reductions Strategies

LDV Lifecycle GHG Emissions, MMtCO₂e

- CAFE + Low Carbon Fuel Standard w. High VMT Growth
- CAFE + Low Carbon Fuel Standard w. Nominal VMT Growth
- CAFE + Low Carbon Fuel Standard w. No VMT Growth

Year

2015 Target

2025 Target
Strategies for VMT Reduction

• Pricing techniques
  – Congestion
  – Parking
  – Pay as you drive insurance

• Alternative travel modes
  – Mass transit
  – Non-motorized (bike, walk)

• Land use strategies
  – Population densification
  – Smart growth: transit-oriented development, mixed use

• Flexible commutes
  – Telecommuting
  – Flexible schedules, compressed schedules

• Process alteration
  – GHG emissions estimates in Environmental Impact Statements and local government plans
  – Educating public and private sectors
GHG Emissions By Travel Mode - Average Emissions

U.S. average GHG emissions per passenger-mile

- SUV (16 mpg)
- Car (23 mpg)
- Hybrid-electric car (35 mpg)
- Transit Bus (4 mpg)
- Light Rail
- Heavy Rail

Emissions per passenger-mile (gCO2e)

- Actual
- At maximum capacity
Combined Strategies

\[ E = F \times C \times A \]

Results
MN State Strategies can be met by addressing F, C, and A. VMT growth rate is key.
Promising Technologies and Strategies for 2050 Reduction Goal

• Massive electrification of transportation
  – Decarbonize electricity production
  – Electric and plug-in hybrid electric vehicles
  – Electric transit, local and intercity

• Freight mode switching – truck to rail to electric rail

• Second generation biofuels
  – Non-food feedstocks, cellulosic, algal
  – Efficient biochemical and thermochemical conversion
  – Synthetic hydrocarbons likely as well as alcohols and ethers
  – Fuels used mainly for aircraft, trucks

• Land use and system shifts
Conclusions

• We can meet 2015 and 2025 transportation GHG reduction goals
  – Many strategy combinations possible…
  – But, we must start now!
• Fuel efficiency improvements offer significant economic benefits
• Lifecycle analysis is necessary to assess transportation GHG strategies
• Linking land use and transportation planning is key for VMT reduction
Thank You

for a summary of the study, visit
www.cts.umn.edu/Research/GreenhouseGas
Additional Charts
These have backup information that do not necessarily appear in the report
Future Research Related to GHG Emissions and Transportation Sector

• Economic analysis
• Role of fuel prices in reducing VMT
• Role of education
  – In improving fuel economy
  – In transportation choices
• Reducing dependency on conventional coal based electricity
• Health affects
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**
Minnesota Statistics
Compared To U.S.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minnesota</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (\times 10^6)</td>
<td>5.1</td>
<td>296</td>
</tr>
<tr>
<td>Total GHG emissions (\text{MMtCO}_2\text{e})</td>
<td>155</td>
<td>7147</td>
</tr>
<tr>
<td>Emissions/capita (\text{Mt per person})</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>Transportation sector GHG emissions (\text{MMtCO}_2\text{e})</td>
<td>37.2</td>
<td>2000</td>
</tr>
<tr>
<td>Emissions/capita (\text{Mt per person})</td>
<td>7.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Transportation sector % of total emissions</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>Transportation sector GHG emissions growth 1995-2005 (\text{pct})</td>
<td>20</td>
<td>18 (1)</td>
</tr>
<tr>
<td>Total on-road vehicles registered (\times 10^6) (\text{(2)})</td>
<td>4.6</td>
<td>241</td>
</tr>
<tr>
<td>Vehicles per person</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>On-road vehicle fleet growth 1995-2005 (%)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>VMT (\times 10^9)</td>
<td>57</td>
<td>2990</td>
</tr>
<tr>
<td>VMT growth 1995-2005 (%)</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>VMT per person (\times 10^3)</td>
<td>11.2</td>
<td>10.1</td>
</tr>
</tbody>
</table>

(1) Estimated based on CO\(_2\) only transportation emissions of 1,665 (1995) and 1,959 (2005) MMt
(2) Automobiles, light and heavy trucks, buses

Sources: U.S. Census Bureau, Mn Pollution Control Agency, U.S. Department of Transportation, U. S. Energy Information Agency, Bureau of Transportation Statistics, Center for Climate Studies 2008b, Mn Department of Transportation
## Comparison of NHTSA CAFE Phase-In, CAFE Linear and California Standards MPG

<table>
<thead>
<tr>
<th>Year</th>
<th>Fleet Comp CAFE Phase In</th>
<th>Fleet Comp CAFE &quot;Linear&quot;</th>
<th>Fleet Comp CA 49 State</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>27.8</td>
<td>23.7</td>
<td>26.7</td>
</tr>
<tr>
<td>2012</td>
<td>29.2</td>
<td>25</td>
<td>29.5</td>
</tr>
<tr>
<td>2013</td>
<td>30.5</td>
<td>26.2</td>
<td>29.9</td>
</tr>
<tr>
<td>2014</td>
<td>31.0</td>
<td>27.5</td>
<td>30.4</td>
</tr>
<tr>
<td>2015</td>
<td>31.6</td>
<td>28.7</td>
<td>31.3</td>
</tr>
</tbody>
</table>
## Vehicle Efficiency Technology

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

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

Feebates

<table>
<thead>
<tr>
<th>Feebate parameters</th>
<th>Fuel economy, mpg</th>
<th>Rebate or fee</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 mpg pivot point (.033 gal/mi), E10 gasoline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>$1782 rebate</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>$1332 rebate</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>$774 rebate</td>
<td></td>
</tr>
<tr>
<td>$18/gram CO$_2$e/mile rebate/surcharge rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>$1062 fee</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>$2664 fee</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>$5310 fee</td>
<td></td>
</tr>
</tbody>
</table>

Data assumes 100% conversion of MPG to grams per mile CO$_2$e emissions

<table>
<thead>
<tr>
<th>Estimated Reduction 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>$18 g/ mi feebate policy alone</td>
</tr>
<tr>
<td>$36 g/ mi feebate policy alone</td>
</tr>
<tr>
<td>$18 g/ mi feebate policy and California standards combined</td>
</tr>
</tbody>
</table>

Based on McManus 2007 and LEAP model 2015 California standards reduction with +/- 20% uncertainty

Estimated contribution to Minnesota 2015 transportation GHG reduction goal from LDV feebate policy implemented in Minnesota as a member of Midwestern states policy coalition.
Lifecycle GHG Emissions

[Graph showing lifecycle GHG emissions for different energy sources and technologies, including gasoline upstream, gasoline tailpipe, biomass processing, feedstock production, and electricity generation.]
# VMT Reductions from Smart Growth Strategies in Other U.S. Regions

<table>
<thead>
<tr>
<th>Area</th>
<th>Years</th>
<th>VMT reduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany</td>
<td>2000 - 2015</td>
<td>7 - 14%</td>
</tr>
<tr>
<td>California</td>
<td>2000 - 2015</td>
<td>3 - 10%</td>
</tr>
<tr>
<td>Portland</td>
<td>1995 - 2010</td>
<td>6 - 8%</td>
</tr>
<tr>
<td>Puget Sound</td>
<td>2005 - 2050</td>
<td>10 - 25%</td>
</tr>
<tr>
<td>Sacramento</td>
<td>2001 - 2015</td>
<td>7%</td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>2000 - 2015</td>
<td>3%</td>
</tr>
</tbody>
</table>

*relative to a do-nothing alternative, in final year
VMT Reductions – Inputs for Estimates

- Energy intensity per passenger mile (lowest for trains)

<table>
<thead>
<tr>
<th>Mode of travel</th>
<th>Number of vehicles</th>
<th>Vehicle-miles</th>
<th>Passenger-miles</th>
<th>Load factor **</th>
<th>Amount of gasoline eq (gallons) (KWH*)</th>
<th>Energy intensities (Btu per passenger-mile)</th>
<th>Energy use (million Btu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorcycles</td>
<td>1.9E+05</td>
<td>3.3E+08</td>
<td>3.7E+08</td>
<td>1.1</td>
<td>6.6E+06</td>
<td>2.5E+03</td>
<td>2.3E+03</td>
</tr>
<tr>
<td>Automobiles</td>
<td>2.5E+06</td>
<td>2.8E+10</td>
<td>4.4E+10</td>
<td>1.6</td>
<td>1.3E+09</td>
<td>5.7E+03</td>
<td>3.6E+03</td>
</tr>
<tr>
<td>Light-Duty Trucks</td>
<td>1.9E+06</td>
<td>2.4E+10</td>
<td>4.2E+10</td>
<td>1.7</td>
<td>1.5E+09</td>
<td>7.5E+03</td>
<td>4.4E+03</td>
</tr>
<tr>
<td>Tranist - Bus</td>
<td>&gt; 853</td>
<td>6.3E+07</td>
<td>5.5E+08</td>
<td>8.7</td>
<td>1.2E+07</td>
<td>2.4E+04</td>
<td>2.8E+03</td>
</tr>
<tr>
<td>Transit - Rail</td>
<td>23</td>
<td>1.6E+06</td>
<td>5.4E+07</td>
<td>34.3</td>
<td>1.2E+07</td>
<td>2.6E+04</td>
<td>7.5E+02</td>
</tr>
</tbody>
</table>

*Hiawatha LRT for the year 2005

**Load factor is unknown for the State of Minnesota, estimates for the entire US were used instead, except for LRT

- Metro Council data; basis for calculating VMT reductions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Metro</th>
<th>Non-metro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip length (miles)</td>
<td>6.6</td>
<td>12.7</td>
</tr>
<tr>
<td>Trip rate (trips per day)</td>
<td>4.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Vehicle occupancy (passengers per vehicle)</td>
<td>1.35</td>
<td>1.40</td>
</tr>
<tr>
<td>Mode split - auto</td>
<td>89.6%</td>
<td>94.5%</td>
</tr>
<tr>
<td>Mode split - transit</td>
<td>2.3%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Mode split - walk/bike</td>
<td>8.1%</td>
<td>5.3%</td>
</tr>
</tbody>
</table>
GHG Emissions By Travel Mode- Average And Marginal Emissions

- **Average CO2-e (g/PMT)**
- **Marginal CO2-e (g/PMT)**
- **Average CO2-e (g/seat-mi)**

- Motorcycle
- LDT/SUV
- Car
- HEV Car
- Electric Vehicle
- Bus
- Light Rail
- Commuter Rail
- Heavy Rail
- Ferry
- Airplane
Cap and Trade, Carbon Tax

• Both are challenging to implement for state transportation systems
  – Taxes politically unpopular
  – How to set dollar amount
  – Demand may be inelastic – i.e., limited choices on fuels

• Cap and trade technologically difficult for millions of vehicles (emissions must be tracked)
Policy Impacts On MN Reduction Goals
Range of Percent Reductions Against 2015 and 2025 Goals

<table>
<thead>
<tr>
<th>Strategy</th>
<th>2015</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GHG reduction,</td>
<td>Percent of 2015 Goal</td>
</tr>
<tr>
<td></td>
<td>MMTCO₂e</td>
<td></td>
</tr>
<tr>
<td>CAFE (with proposed phase-in)</td>
<td>2.7 - 4.1</td>
<td>49 - 73%</td>
</tr>
<tr>
<td>California tailpipe GHG standards</td>
<td>2.9 - 4.3</td>
<td>51 - 77%</td>
</tr>
<tr>
<td>CAFE with comprehensive smart growth</td>
<td>3.0 - 4.5</td>
<td>54 - 80%</td>
</tr>
<tr>
<td>CAFE with low carbon fuel standard (LCFS)</td>
<td>3.5 - 5.2</td>
<td>62 - 94%</td>
</tr>
<tr>
<td>California standards with comprehensive smart growth and LCFS</td>
<td>3.9 - 5.9</td>
<td>70 - 105%</td>
</tr>
</tbody>
</table>

Ranges show +/- 20% uncertainty around nominal LEAP model value.
<table>
<thead>
<tr>
<th>Strategy</th>
<th>2015</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GHG reduction, MMTCO$_2$e</td>
<td>Percent of 2015 Goal</td>
</tr>
<tr>
<td>CAFE (with proposed phase-in)</td>
<td>3.4</td>
<td>61%</td>
</tr>
<tr>
<td>California tailpipe GHG standards</td>
<td>3.6</td>
<td>64%</td>
</tr>
<tr>
<td>CAFE with comprehensive smart growth</td>
<td>3.8</td>
<td>67%</td>
</tr>
<tr>
<td>CAFE with low carbon fuel standard (LCFS)</td>
<td>4.4</td>
<td>78%</td>
</tr>
<tr>
<td>California standards with comprehensive smart growth and LCFS</td>
<td>4.9</td>
<td>88%</td>
</tr>
</tbody>
</table>
VMT Reductions From Land Use And System Shifts

<table>
<thead>
<tr>
<th>Policy</th>
<th>Estimated VMT Reduction in 2025, Relative to the Do-Nothing Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do-nothing Alternative (0.9% annual growth)</td>
<td>0.0%</td>
</tr>
<tr>
<td>Smart Growth - Limited</td>
<td>1.5%</td>
</tr>
<tr>
<td>Smart Growth - Comprehensive</td>
<td>3.4%</td>
</tr>
<tr>
<td>Smart Growth - Aggressive</td>
<td>5.3%</td>
</tr>
<tr>
<td>Construction of Light Rail Transit (LRT) Network</td>
<td>2.2%</td>
</tr>
<tr>
<td>Construction of Bus Rapid Transit (BRT) Network</td>
<td>2.2%</td>
</tr>
<tr>
<td>Construction of Commuter Rail</td>
<td>0.1%</td>
</tr>
<tr>
<td>General Transit Improvements</td>
<td>0.3%</td>
</tr>
<tr>
<td>Employer / Municipal Parking-Pricing Plans</td>
<td>0.3%</td>
</tr>
<tr>
<td>Pay-As-You-Drive (PAYD) Insurance (10% penetration rate)</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

Do-nothing Alternative (0.9% annual growth)