Pathways to Transportation Decarbonization
A partnership with MnDOT, MPCA, MDA, EQB, Department of Commerce, and the McKnight Foundation

Tim Sexton, Chief Sustainability Officer, Minnesota Department of Transportation

12 June 2019
Minnesota Pathways to Decarbonization

- Work with technical experts from the public, private, and nonprofits sectors to inform modeling assumptions and strategies that should be considered.
  April – June 2019

- Model different pathways for decarbonizing transportation.
  April – May 2019

- Meet with the public at locations around the state to hear their feedback and thoughts on strategies.
  May – June 2019

Department of Transportation
<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Time</th>
<th>Topic</th>
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</thead>
<tbody>
<tr>
<td>2:30 – 2:40</td>
<td>Registration and refreshments</td>
<td>3:35 – 3:50</td>
<td>Clarifying Questions on Modeling</td>
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<tr>
<td>2:40 – 2:50</td>
<td>Introduction</td>
<td>3:50 – 4:05</td>
<td>Table Discussion</td>
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<td>2:50 – 3:05</td>
<td>Welcome</td>
<td>4:05 – 4:20</td>
<td>Survey</td>
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<tr>
<td>3:05 – 3:15</td>
<td>Icebreaker questions</td>
<td>4:20 – 4:30</td>
<td>Wrap up</td>
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<tr>
<td>3:15 – 3:35</td>
<td>Modeling Presentation</td>
<td>4:30pm</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
Meeting Ground Rules

• Phones at the ready!
• No acronyms
• Respectful listening
• Step up, Step back
Icebreaker Questions

Please use your mobile devices to go to this link to participate in a live polling exercise

Visit the Mentimeter

Log-in using the code shown on the screen
State Context and Emissions

Abby Finis, Senior Energy Planner, Great Plains Institute
The Next Generation Energy Act requires the state to reduce greenhouse gas emissions 80% by 2050, setting interim reduction targets in 2015 and 2025.
Progress Towards Next Generation Energy Act Goals

Historical Emissions in Minnesota and Next Generation Energy Act Goals

- 2005 Emissions Levels:
  - 2015: 15%
  - 2025: 30%
  - 2050: 80%

![Graph showing historical emissions and Next Generation Energy Act goals](mndot.gov)
Changes in Emissions by Sector

Minnesota Emissions by Sector, 2005-2016

- Transportation: -3.31M (-8%)
- Electricity generation: -16.41M (-29%)
- Agriculture, Forestry and Land use: -4.52M (-12%)
- Industrial: +2.99M (+17%)
- Residential: +0.94M (+11%)
- Commercial: +0.1M (+1%)
- Waste: -0.13M (-6%)

Source: Minnesota Pollution Control Agency, Greenhouse Gas Emission Inventory, 2005-2016

mndot.gov
Focus of this Study

Minnesota Emissions Profile

- Agriculture: 32%
- Industry: 20%
- Buildings: 17%
- Waste: 1%
- Electricity Generation: 1%
- Surface Transportation: 1%
- Other Transportation: 4%

- Light-duty automobiles: 25%
- Light-duty trucks: 32%
- Medium-duty trucks: 17%
- Heavy-duty trucks: 20%
- Buses: 1%
- Motorcycles: 1%
- Mobile air conditioning: 4%
Emissions from Surface Transportation in Minnesota

- Emissions from Surface Transportation were 8% below 2005 levels in 2016.
- The goal of this analysis is to model measures and actions that could help Minnesota meet 2025 and 2050 Next Generation Energy Act goals for transportation.
Why Model?

• Explore:
  • Opportunities and challenges
  • Actions that get the most reduction
  • When they need to happen
  • How they interact
  • How they can be combined
  • Start the conversation
Pathways to Decarbonization Modeling

Jessi Wyatt, Energy Planner and Analyst, Great Plains Institute

Modeling by Energy and Environmental Economics, Inc. (E3)
Inputs

• Not prescriptive, just exploratory
• Technical stakeholder advisory group met to discuss inputs, metrics, and constraints
• Resulted in two scenarios
Scenarios in Action

Total Surface Transportation Emissions by Scenario

Historical Emissions

- 15% below 2005 levels
- 30% below 2005 levels
- 80% below 2005 levels
- 100% below 2005 levels

Note all results today focus on 80x50 scenario, more detail can be found in the appendix.
Actions that can reduce emissions in transportation

**Efficiency**
- Fuel economy and hybrid vehicles
- Reduce driving

**Electric vehicles**

**Low-carbon fuels**
- Increase low-carbon biofuels
- Zero- or low-carbon electricity production

**Refrigerants**
55% blend of low-carbon biofuels in gasoline and diesel
90% zero-carbon electricity

Start ramping up sales of electric vehicles in light, medium, and heavy duty vehicles

Reduce urban miles traveled by 6% (relative to reference)
30% sales of hybrid vehicles in medium and heavy duty

40% electric vehicle sales in light duty
750,000 electric passenger vehicles on the road
50% electric bus sales

20% blend of low-carbon biofuels in gasoline and diesel

100% of new vehicles sold use low global warming potential refrigerants

55% blend of low-carbon biofuels in gasoline and diesel
90% zero-carbon electricity

50,000 electric passenger vehicles on the road
50% electric bus sales

Reduce urban miles traveled by 10%

80% electric vehicle sales in light duty

100% of new vehicles sold use low global warming potential refrigerants

Reduce urban miles traveled by 10%
Modeling - Results
Two Ways to Think About Transformations

1. Remaining Emissions in MN
2. Emission Reductions

Greenhouse Gas Emissions (Million Short Tons CO2e)

Reference Scenario
Emissions Goals

1. Remaining Emissions in MN
2. Emission Reductions
Remaining Emissions in Minnesota by Type
80x50 Scenario

GHG emissions (MST CO2e)

- Reference
- Mobile Refrigerants
- Motorcycle
- RV
- Buses
- Heavy Duty Trucks
- Medium Duty Trucks
- Light Duty Trucks
- Light Duty Autos

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What are the kinds of policies, regulations, and incentives that can help get us there?

Improve **fuel economy**:
- Federal or state vehicle efficiency standards
From Modeling to Implementation

What are the kinds of policies, regulations, and incentives that can help get us there?

Reduce driving:

• Smart, dense city design
• Neighborhoods built for biking, walking, and rolling
• Carpooling incentives
• Improved public transit
What are the kinds of policies, regulations, and incentives that can help get us there?

Increase sales of electric vehicles:

• Consumer rebates
• State vehicle targets
• Public and workplace charging stations
From Modeling to Implementation

What are the kinds of policies, regulations, and incentives that can help get us there?

Reduce the carbon intensity of biofuels:

- Improved agricultural and soil practices,
- Process efficiency
- Low-carbon fuel standard
What are the kinds of policies, regulations, and incentives that can help get us there?

Increase lower-carbon electricity:

- Clean electricity standards
- Utility greenhouse gas reduction goals
- Retire coal plants
Thank you!
Questions?
1. What do you see as the most immediate opportunities you see in your community achieving a transportation system with reduced emissions?

“We have a real opportunity to ....”

Use up to three post-its to share your insights.
• 2. What do you see as the barriers in your community to achieving a transportation system with reduced emissions?
  “We will need to overcome ....”

Use up to three post-its to share your insights.
Interactive Polling: Round 2

Please use your mobile devices to go to the following link to participate in a live exercise

Visit Mentimeter

Log-in using the code on the screen.
Public meetings around the state in five total cities: Minneapolis, Bemidji, Duluth, Marshall, and Rochester

Feedback will be collected and put into a report, with the modeling and results, by August 2019

Opportunities for additional feedback are available
Thank you!

All content about the project will be updated and available on the MnDOT Sustainability website:

✓ Webinar recording
✓ Survey
✓ Open Comment portal
✓ Public Meeting details
Appendix with Modeling Methodologies
Modeling Scope

- Transportation emissions made up 26% of 2016 GHG emissions in Minnesota

- This project will focus on surface transportation, 20% of 2016 emissions
  - This excludes aviation, marine, rail, and military emissions

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<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Surface Transportation</td>
<td>Light Duty Autos</td>
<td>Stock Rollover</td>
<td>8.0</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Light Duty Trucks</td>
<td>Stock Rollover</td>
<td>10.0</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td>Medium Duty Trucks</td>
<td>Stock Rollover</td>
<td>5.3</td>
<td>17%</td>
</tr>
<tr>
<td></td>
<td>Heavy Duty Trucks</td>
<td>Stock Rollover</td>
<td>6.2</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>Buses</td>
<td>Stock Rollover</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>RVs</td>
<td>Total Energy by Fuel</td>
<td>0.1</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Motorcycles</td>
<td>Total Energy by Fuel</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>Mobile Air Conditioning</td>
<td>Total Emissions</td>
<td>1.4</td>
<td>4%</td>
</tr>
<tr>
<td>All Sectors</td>
<td></td>
<td></td>
<td>31.5</td>
<td>100%</td>
</tr>
</tbody>
</table>

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Modeling Scope

PCA Inventory Emissions ("PCA Accounting")

- Agriculture
- Industry
- Waste
- Buildings
- Electricity Generation
- Other Transportation
- Surface Transportation

Upstream Emissions in MN ("Upstream Emissions")

- Agriculture
- Industry
- Waste
- Buildings
- Electricity Generation
- Other Transportation
- Surface Transportation
- Biofuel Feedstock Production*
- Biofuel Production*
- Electricity Generation for ZEVs*

*Size of upstream emissions are illustrative only
Abbreviation Key

### Vehicle Types

- **LDA** = light-duty automobiles (passenger cars)
- **LDT** = light-duty trucks (e.g. smaller pickup trucks)
- **LDV** = light-duty vehicles (LDAs + LDTs)
- **MDV** = medium-duty vehicles (e.g. larger pickup trucks)
- **HDV** = heavy-duty vehicles (e.g. semi-trailer trucks)

### Other

- **BEV/EV** = battery electric vehicle/electric vehicle
- **PHEV** = plug-in hybrid electric vehicle
- **VMT** = vehicle-miles traveled
- **80x50** = 80% reductions in GHG emissions by 2050
- **100x50** = 100% reductions in GHG emissions by 2050
E3’s PATHWAYS Model

- Economy-wide infrastructure-based GHG and energy analysis
  - Captures “infrastructure inertia” reflecting lifetimes and vintages of buildings, vehicles, equipment
  - Models physical energy flows within all sectors of the economy
  - Allows for rapid comparison between user-defined scenarios

- Scenarios test “what if” questions
  - Reference or counterfactual scenario for consistent comparison in future years
  - Multiple mitigation scenarios can be compared that each meet the same GHG emissions goal
**PATHWAYS Modeling Framework**

### Demand Sectors

- **End-Use Energy Services Demand**
  - How many miles do Minnesotans drive per year (2020-2050)?

- **Stock Rollover**
  - How many electric vehicles are on the road?

### Supply Sectors

- **Electricity Supply**
  - What is the % of zero-carbon generation on the grid?

- **Pipeline Gas Supply**

- **Other Fuels (Gasoline, Diesel, Hydrogen, etc.)**
  - What is % blend of biofuels?

### Model Outputs

- How many GHG emissions are saved?
Categories of Model Outputs

- Technology stocks & sales (e.g. Household appliances, Vehicles)
- Service demands and activity drivers (e.g. Vehicle miles traveled)
- Energy demand
- Energy supply (e.g. Electricity generation, Natural gas supply, Biofuel blends)
- Greenhouse gas emissions

All outputs are tracked by sector, fuel and year
Example of Modeling Methodology
Stock Rollover for Zero-Emission Vehicles

- Light duty vehicles have an average life of ~15 years, which means they will need an average of 2 replacements over the next 30 years
  - Even if Minnesota reaches 100% of new sales as Zero Emission Vehicle alternatives, it will take significant time for existing gasoline vehicles to come off the road.
  - Delayed progress in sales could lead to costly programs to retire the existing fleet early (e.g. cash for clunkers programs).

% of New LDV Sales

Total Light Duty Vehicles
Scenario Definitions

• **Reference Scenario**
  • Business as usual scenario including current policies (e.g. expected adoption of electric vehicles)

• **80x50 Scenario**
  • One pathway that meets an 80% reduction in surface transportation greenhouse gas emissions by 2050 (using 2005 levels as a starting point)

  *Not the only way to get to 80x50 and not a recommendation of what MN should do*

• **100x50 Scenario**
  • One pathway that meets a 100% reduction in surface transportation greenhouse gas emissions by 2050 (using 2005 levels as a starting point)

  *Not the only way to get to 100x50 and not a recommendation of what MN should do*
<table>
<thead>
<tr>
<th>Measure</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Economy Standards</td>
<td>Included 2021-2026</td>
<td></td>
</tr>
<tr>
<td>LDV VMT Reductions</td>
<td>3% below Reference</td>
<td>5% below Reference</td>
</tr>
<tr>
<td>Light-duty vehicles</td>
<td>40% sales of EVs</td>
<td>80% sales of EVs</td>
</tr>
<tr>
<td>Medium-duty vehicles</td>
<td>30% sales of hybrids, 10% sales of EVs</td>
<td>30% sales of hybrids, 50% sales of EVs</td>
</tr>
<tr>
<td>Heavy-duty vehicles</td>
<td>30% sales of hybrids, 10% sales of EVs</td>
<td>30% sales of hybrids, 50% sales of EVs</td>
</tr>
<tr>
<td></td>
<td>6.5% sales of CNG vehicles</td>
<td>6.5% sales of CNG vehicles</td>
</tr>
<tr>
<td>Biofuels</td>
<td>20% blend, ~40% reduction in CI relative to 2016</td>
<td>55% blend, ~50% reduction in CI relative to 2016</td>
</tr>
<tr>
<td>Electricity</td>
<td>22% reduction in carbon intensity relative to 2016</td>
<td>90% reduction in carbon intensity relative to 2016</td>
</tr>
<tr>
<td>Mobile Refrigerants</td>
<td>100% sales by 2035</td>
<td></td>
</tr>
</tbody>
</table>
### Key Scenario Assumptions by Scenario

#### 100x50 Scenario

<table>
<thead>
<tr>
<th>Measure</th>
<th>2030</th>
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<tr>
<td><strong>Fuel Economy Standards</strong></td>
<td>Included 2021-2026</td>
<td></td>
</tr>
<tr>
<td><strong>LDV VMT Reductions</strong></td>
<td>5% below Reference</td>
<td>10% below Reference</td>
</tr>
<tr>
<td><strong>Light-duty vehicles</strong></td>
<td>60% sales of EVs</td>
<td>100% sales of EVs (by 2040)</td>
</tr>
<tr>
<td><strong>Medium-duty vehicles</strong></td>
<td>30% sales of hybrids</td>
<td>40% sales of hybrids</td>
</tr>
<tr>
<td></td>
<td>20% sales of EVs</td>
<td>60% sales of EVs</td>
</tr>
<tr>
<td><strong>Heavy-duty vehicles</strong></td>
<td>30% sales of hybrids</td>
<td>33.5% sales of hybrids</td>
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<td></td>
<td>20% sales of EVs</td>
<td>60% sales of EVs</td>
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<tr>
<td></td>
<td>6.5% sales of CNG vehicles</td>
<td>6.5% sales of CNG vehicles</td>
</tr>
<tr>
<td><strong>Biofuels</strong></td>
<td>20% blend</td>
<td>100% blend</td>
</tr>
<tr>
<td></td>
<td>~50% reduction in CI relative to 2016</td>
<td>100% reduction in CI relative to 2016</td>
</tr>
<tr>
<td><strong>Electricity</strong></td>
<td>22% reduction in carbon intensity relative to 2016</td>
<td>100% carbon-free</td>
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<tr>
<td><strong>Mobile Refrigerants</strong></td>
<td>100% sales by 2025</td>
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## Key Drivers for Reference Scenario

<table>
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<tr>
<th>Sector</th>
<th>Key Driver</th>
<th>Compound annual growth rate proposed for this study [%]</th>
<th>Data Source</th>
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<tr>
<td>Light-Duty Autos and Trucks</td>
<td>VMT</td>
<td>1% (2016-2025) 0.44% (2030-3050)</td>
<td>Projected growth through 2025, trending towards Population growth by 2030</td>
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<td>Medium-Duty Vehicles</td>
<td>VMT</td>
<td>1.4%</td>
<td>EIA AEO 2019</td>
</tr>
<tr>
<td>Heavy-Duty Vehicles</td>
<td>VMT</td>
<td>1.4%</td>
<td>EIA AEO 2019</td>
</tr>
<tr>
<td>Buses</td>
<td>VMT</td>
<td>1.4%</td>
<td>EIA AEO 2019</td>
</tr>
<tr>
<td>RVs</td>
<td>Gasoline consumption</td>
<td>-0.9%</td>
<td>EIA AEO 2019</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>Gasoline consumption</td>
<td>-0.9%</td>
<td>EIA AEO 2019</td>
</tr>
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</table>
## Reference Scenario Assumptions

<table>
<thead>
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<th>Sector</th>
<th>Measure</th>
<th>Assumption</th>
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<tr>
<td>LDVs</td>
<td>Federal Fuel Economy Standards</td>
<td>Included through 2020, not extended 2021-2026</td>
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<tr>
<td>LDVs</td>
<td>LDV EV Sales</td>
<td>8.9% sales of EVs by 2030, 16% by 2050 (from EIA AEO)</td>
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<td>LDVs</td>
<td>LDV VMT growth</td>
<td>1% growth 2016-2025, transitioning to 0.44% growth by 2030 (tracking with population)</td>
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<tr>
<td>MDVs</td>
<td>MDV EV + Hybrid Sales</td>
<td>N/A</td>
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<tr>
<td>MDVs</td>
<td>MDV VMT growth</td>
<td>1.4% 2016-2050</td>
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<tr>
<td>HDVs</td>
<td>HDV EV + Hybrid Sales</td>
<td>N/A</td>
</tr>
<tr>
<td>HDVs</td>
<td>HDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>Buses</td>
<td>Electric Buses</td>
<td>N/A</td>
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<tr>
<td>Buses</td>
<td>Bus VMT growth</td>
<td>1.4% 2016-2050</td>
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<tr>
<td>Biofuels</td>
<td>Ethanol</td>
<td>7.4% average blend in 2016 (energy basis)</td>
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<td>Biofuels</td>
<td>Ethanol carbon intensity</td>
<td>Constant carbon intensity</td>
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<tr>
<td>Biofuels</td>
<td>Biodiesel</td>
<td>20% biodiesel by 2018 (12.5% annual average)</td>
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<tr>
<td>Biofuels</td>
<td>Biodiesel carbon intensity</td>
<td>Constant carbon intensity</td>
</tr>
<tr>
<td>Electricity</td>
<td>Electricity</td>
<td>48% zero-carbon generation statewide, 22% decrease in carbon intensity by 2025</td>
</tr>
<tr>
<td>RVs</td>
<td>Biofuels for RVs</td>
<td>N/A</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>Electric Motorcycles</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile Refrigerants</td>
<td>Lower GWP Refrigerants</td>
<td>N/A</td>
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## 80x50 Scenario Assumptions

<table>
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<tbody>
<tr>
<td>LDVs</td>
<td>Federal Fuel Economy Standards</td>
<td>Extended through 2026</td>
</tr>
<tr>
<td></td>
<td>LDV EV Sales</td>
<td>40% sales by 2030, 80% by 2050</td>
</tr>
<tr>
<td></td>
<td>LDV VMT growth</td>
<td>3% reduction relative to reference (for whole state) by 2030, 5% by 2050</td>
</tr>
<tr>
<td>MDVs</td>
<td>MDV EV + Hybrid Sales</td>
<td>40% sales by 2030, 80% by 2050</td>
</tr>
<tr>
<td></td>
<td>MDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>HDVs</td>
<td>HDV EV + Hybrid Sales</td>
<td>40% sales by 2030, 80% by 2050</td>
</tr>
<tr>
<td></td>
<td>HDV CNG Vehicle Sales</td>
<td>6.5% sales by 2030</td>
</tr>
<tr>
<td></td>
<td>HDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>Buses</td>
<td>Electric Buses</td>
<td>50% sales by 2030 (of those 100% BEV)</td>
</tr>
<tr>
<td></td>
<td>CNG Buses</td>
<td>7.5% sales by 2030</td>
</tr>
<tr>
<td></td>
<td>Bus VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Ethanol</td>
<td>20% blend by 2030, 55% by 2050</td>
</tr>
<tr>
<td></td>
<td>Ethanol carbon intensity</td>
<td>Declining carbon intensity (58% improvement by 2030, holding constant thereafter)</td>
</tr>
<tr>
<td></td>
<td>Biodiesel</td>
<td>20% blend by 2030, 55% by 2050</td>
</tr>
<tr>
<td></td>
<td>Biodiesel Carbon Intensity</td>
<td>Declining carbon intensity (25% improvement by 2030, 50% improvement by 2050)</td>
</tr>
<tr>
<td>Electricity</td>
<td>Electricity</td>
<td>90% zero-carbon generation statewide by 2050</td>
</tr>
<tr>
<td>RVs</td>
<td>Biofuels for RVs</td>
<td>20% blend by 2030, 55% by 2050</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>Electric Motorcycles</td>
<td>50% of motorcycles are electric by 2050</td>
</tr>
<tr>
<td>Mobile Refrigerants</td>
<td>Lower GWP Refrigerants</td>
<td>All vehicles sold by 2035 have low-GWP refrigerant</td>
</tr>
</tbody>
</table>
## 100x50 Scenario Assumptions

<table>
<thead>
<tr>
<th>Sector</th>
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<tbody>
<tr>
<td>LDVs</td>
<td>Federal Fuel Economy Standards</td>
<td>Extended through 2026</td>
</tr>
<tr>
<td></td>
<td>LDV EV Sales</td>
<td>60% by 2030, 100% by 2040</td>
</tr>
<tr>
<td></td>
<td>LDV VMT growth</td>
<td>5% reduction relative to reference (for whole state) by 2030, 10% by 2050</td>
</tr>
<tr>
<td>MDVs</td>
<td>MDV EV + Hybrid Sales</td>
<td>50% sales by 2030, 100% by 2050</td>
</tr>
<tr>
<td></td>
<td>MDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>HDVs</td>
<td>HDV EV + Hybrid Sales</td>
<td>50% sales by 2030, 100% by 2050</td>
</tr>
<tr>
<td></td>
<td>HDV CNG Vehicle Sales</td>
<td>6.5% sales by 2030</td>
</tr>
<tr>
<td></td>
<td>HDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>Buses</td>
<td>Electric Buses</td>
<td>50% sales by 2030 (of those 100% BEV)</td>
</tr>
<tr>
<td></td>
<td>CNG Buses</td>
<td>7.5% sales by 2030</td>
</tr>
<tr>
<td></td>
<td>Bus VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Ethanol</td>
<td>20% blend by 2030, 100% by 2050</td>
</tr>
<tr>
<td></td>
<td>Ethanol carbon intensity</td>
<td>Declining carbon intensity to carbon-neutral fuels by 2050</td>
</tr>
<tr>
<td></td>
<td>Biodiesel</td>
<td>20% blend by 2030, 100% by 2050</td>
</tr>
<tr>
<td></td>
<td>Biodiesel Carbon Intensity</td>
<td>Declining carbon intensity to carbon-neutral fuels by 2050</td>
</tr>
<tr>
<td></td>
<td>Electricity</td>
<td>100% zero-carbon generation statewide (emission factor goes to zero by 2050)</td>
</tr>
<tr>
<td>RVs</td>
<td>Biofuels for RVs</td>
<td>20% blend by 2030, 100% by 2050</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>Electric Motorcycles</td>
<td>100% of motorcycles are electric by 2050</td>
</tr>
<tr>
<td>Mobile Refrigerants</td>
<td>Lower GWP Refrigerants</td>
<td>All vehicles sold by 2025 have low-GWP refrigerant</td>
</tr>
</tbody>
</table>
• Fuel economy standards for light-duty vehicles has a significant impact on the energy consumption and emissions from internal combustion engine vehicles

• Reference Scenario
  • Include improved vehicle fuel economy through 2020
  • 80x50 and 100x50
  • Include extended improvements through 2026
Changes in Urban Vehicle-Miles Traveled

• There are many ways to reduce urban or metro vehicle-miles traveled (VMT)* including improved public transit, smart city design, carpooling, walking or biking
• Reference
  • Near-term growth (1%) through 2025, transitioning to population growth rate by 2030 (0.44%)
• 80x50 Scenario
  • Reductions of 6% by 2030 and 10% by 2050 (in light-duty vehicles only)
• 100x50 Scenario
  • Reductions of 10% by 2030 and 20% by 2050 (in light-duty vehicles only)

VMT reductions in urban areas can provide significant co-benefits for cities. This analysis only captures direct changes in energy consumption, GHG emissions, and statewide air pollutants.

*Urban and metro VMT was assumed to be 49% of total statewide VMT. No VMT reductions were assumed outside urban areas.
• Existing refrigerants in vehicles have a very high global warming potential (GWP). We assume that new vehicles can switch to a low-GWP refrigerant (e.g. CO2). Successful action in MN will depend on other states (e.g. CA) and US EPA.

• Reference
  • Grows with total number of vehicles (0.44% per year)

• 80x50 Scenario
  • All new cars sold by 2035 use low GWP refrigerant

• 100x50 Scenario
  • All new cars sold by 2025 use low GWP refrigerant
• We assume that biofuel blend rates hold constant in the Reference scenario, and slowly ramp up over time in the 80x50 and 100x50 scenarios.
• Biofuels are treated as technology-agnostic, to leave room for either conventional or advanced biofuels to meet MN’s need for low-carbon fuels.
• If conventional biofuels are blended at rates beyond ~20%, fueling infrastructure and vehicle fleet factors will need to be addressed.
Biofuels are a key measure to reduce GHG emissions from vehicles that use gasoline and diesel. We have assumed that carbon intensities are reduced through one of the following measures:

- Agricultural practices
- Process efficiency and renewable energy substitution
- Carbon capture and storage
- Advanced biofuel production
- Reference
  - Maintain current carbon intensity (CI)
- 80x50 Scenario
  - Low-carbon diesel: 50% reduction in CI by 2050
  - Low-carbon gasoline: 58% reduction in CI by 2050
- 100x50 Scenario
  - 100% reduction in CI by 2050

ILUC = International Land Use Change. No emissions sources outside of MN were included.
• As electric vehicles are more prevalent, it is important to also decarbonize the sources of electricity generation within the state

• Reference
  • Moderate reductions due to fossil retirements (20% reduction in current carbon intensity by 2025)

• 80x50 Scenario
  • 90% carbon-free electricity by 2050

• 100x50 Scenario
  • 100% carbon-free electricity by 2050
• Current ethanol carbon intensity comes from the 2017 USDA Ethanol LCA report. “2014 Current Conditions” is used as the 2016 value.

• Current biodiesel carbon intensity comes from the Argonne National Laboratory GREET model, calculated for Midwest-produced soybean biodiesel.

• 2030 carbon intensity reduction assumption for ethanol in the 80x50 and 100x50 scenarios comes from the “2022 Building Blocks” carbon intensity in the 2017 USDA Ethanol LCA report (carbon intensity is assumed to be reduced by the ratio between the 2014 current conditions and 2022 Building Blocks numbers)

• Less data is available on the carbon intensity reduction potential for biodiesel, so simple assumptions are made on future carbon intensity

• Indirect Land Use Change is not included

• Current electricity carbon intensity is calculated from EIA and MN PCA data

• 2025 electricity carbon intensity in all three scenarios is assumed to be 22% below 2016 levels, based on projected near-term coal retirements

• 2050 carbon intensity for 80x50 scenario is calculated based on 10% natural gas generation
• **80x50 Scenario**
  - Largest emission reductions are in light-duty vehicles and refrigerants

• **100x50 Scenario**
  - Emission reductions across all sectors
• Upstream emissions from biofuels production and electricity generation are tied to energy demands in transportation but are accounted for in other sectors of the MN economy.

• 80x50 Scenario
  • New electric vehicles and biofuel demands increases upstream emissions from electricity generation and biofuel production

• 100x50
  • Zero-carbon biofuels and electricity generation allow transportation emissions to get to 100x50
Emissions Reductions by Measure
80x50 Scenario, PCA Accounting

- Fuel Economy Standards
- Reduction in Urban Miles Traveled
- Light Duty Electric Vehicles
- Medium Duty Electric and Hybrid Vehicles
- Heavy Duty Electric and Hybrid Vehicles
- Biofuels
- Mobile Refrigerants
- GHG Goals

Greenhouse Gas Emissions (Million Short Tons CO2e)

- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050
Total Energy Consumption by Fuel

- **80x50 Scenario**
  - Efficiency benefits from VMT reductions and switching to electric drive trains in EVs
  - Biofuels in gasoline and diesel increase through 2030

- **100x50 Scenario**
  - Electricity demand from EVs becomes significant share of total energy consumed in surface transportation by 2050
  - All remaining liquid fuels are biofuels by 2050
Total Electricity Demand by Sector

- Electricity demand from new electric vehicles ramps up significantly across all sectors in the 100x50 Scenario. In the 80x50 Scenario new electric loads are predominantly in light-duty vehicles.

- Total electricity demand in MN was about 70 TWh in 2016
Total Low-Carbon Biofuels by Sector

- **80x50 Scenario**
  - Achieves 20% biofuels in transportation by 2030 and 60% by 2050, which increases in-state consumption of low-carbon biofuels

- **100x50 Scenario**
  - Achieves 100% biofuel blend by 2050 for remaining transportation fuels
Zero Emission Vehicle Sales
Light Duty Autos

Electric Vehicle Sales: Light Duty Autos

Stock of Light Duty Autos: Reference

Stock of Light Duty Autos: 80x50

Stock of Light Duty Autos: 100x50

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Zero Emission Vehicle Sales
Light Duty Trucks

Electric Vehicle Sales: Light Duty Trucks

Stock of Light Duty Trucks: Reference

Stock of Light Duty Trucks: 80x50

Stock of Light Duty Trucks: 100x50
Zero Emission Vehicle Sales
Medium Duty Vehicles

Electric and Hybrid Vehicle Sales: Medium Duty Trucks

Stock of Medium Duty Trucks: Reference

Stock of Medium Duty Trucks: 80x50

Stock of Medium Duty Trucks: 100x50
Zero Emission Vehicle Sales
Heavy Duty Vehicles

Electric, Hybrid, and CNG Vehicle Sales: Heavy Duty Trucks

Stock of Heavy Duty Trucks: Reference

Stock of Heavy Duty Trucks: 80x50

Stock of Heavy Duty Trucks: 100x50
Vehicle Class Characterizations

• Vehicle class characterizations are slightly different from what is often used in studies for other jurisdictions, due to the accounting methods used in the MN PCA GHG inventory.

  • In this study, “Medium Duty Vehicles” refers to “Light Commercial Trucks,” which are all commercial trucks with four wheels (often included in the light-duty vehicles category in other studies)

  • Heavy Duty Vehicles refers to all commercial trucks with more than four wheels (this encompasses what is often considered MDVs in other studies)
Air Pollution from Surface Transportation
Statewide Emissions

Particulate Matter (PM2.5)

Emissions of Particulates PM2.5 in 2030

- Reference: 0.0007
- 80x50: 0.0010
- 100x50: 0.0010

Emissions of Particulates PM2.5 in 2050

- Reference: 0.0017
- 80x50: 0.0008
- 100x50: 0.0005

Particulate Matter (PM10)

Emissions of Particulates PM10 in 2030

- Reference: 0.0035
- 80x50: 0.0030
- 100x50: 0.0025

Emissions of Particulates PM10 in 2050

- Reference: 0.0030
- 80x50: 0.0020
- 100x50: 0.0015
Air Pollution from Surface Transportation
Statewide Emissions

Nitrogen Oxides ($\text{NO}_x$)

Volatile Organic Compounds (VOCs)
Reference Scenario Results

Emissions by subsector (PCA accounting): Reference

Emissions by sector (including upstream): Reference

Total Energy Consumption by Fuel: Reference Scenario

Low carbon fuel demand by subsector: Reference

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