This project has an accelerated timeline, and therefore is not meant to be the final word on transportation decarbonization.

This work is meant to be an initial assessment of opportunities within Minnesota and will inform future work.

**Timeline**

- **April**
  - Modeling
  - Technical Presentations*
  - Technical Feedback
  - Public Presentations*

- **May**
  - Methods
  - Draft Results

- **June**
  - Final Results

*Exact dates of future presentations to be determined
<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
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<tbody>
<tr>
<td>2:00</td>
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<td>Introductions &amp; Meeting Overview</td>
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<td>Pathways Modeling Presentation</td>
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<td>Q&amp;A with E3</td>
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<td>Small Group Discussions</td>
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<td>Closing Thoughts &amp; Next Steps</td>
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<td>4:00</td>
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Introductions

Name

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

Tory Clark, Director, Energy + Environmental Economics
Gabe Mantegna, Consultant
Amber Mahone, Partner
Agenda

• Background and Scope
• Summary of Feedback
• Assumptions
• Draft Results
• Next Steps
• Appendix
• This project has an accelerated timeline, and therefore is not meant to be the final word on transportation decarbonization

• This work is meant to be an initial assessment of opportunities within Minnesota and will inform future work
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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<td>Stock Rollover</td>
<td>8.0</td>
<td>25%</td>
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<tr>
<td></td>
<td>Light Duty Trucks</td>
<td>Stock Rollover</td>
<td>10.0</td>
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<td>Medium Duty Trucks</td>
<td>Stock Rollover</td>
<td>5.3</td>
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<tr>
<td></td>
<td>Heavy Duty Trucks</td>
<td>Stock Rollover</td>
<td>6.2</td>
<td>20%</td>
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<td>Buses</td>
<td>Stock Rollover</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
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<td>RVs</td>
<td>Total Energy by Fuel</td>
<td>0.1</td>
<td>0%</td>
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<td>Motorcycles</td>
<td>Total Energy by Fuel</td>
<td>0.2</td>
<td>1%</td>
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<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>
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</table>

Minnesota GHG Emissions
• 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 NG>E goals
Summary of Feedback
Summary of Feedback

• First Technical Stakeholder meeting was held on April 18th
  • ~45 participants attended, representing many different perspectives

• Group was asked for input on:
  • Most important decarbonization strategies
  • Policies to achieve decarbonization
  • Specifics on strategies, policies, data, assumptions

• Strategies offered by the stakeholders fell into categories:
  • Transit/electrified transit/medium and heavy duty electrification
  • Community design and planning
  • Transportation electrification
  • Biofuels and other low carbon fuels

• Detailed input was reflected in the modelling that will be presented today
Modeling Scope

PCA Inventory Emissions ("PCA Accounting")

Upstream Emissions in MN ("Upstream Emissions")

*Size of upstream emissions are illustrative only
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 GHGs by 2050 (below 2005 levels)

  *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 GHGs by 2050 (below 2005 levels)

  *Not the only way to get to 100x50 and not a recommendation of what MN should do*
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
Categories of Key Assumptions

• Efficiency
  • Vehicle fuel economy
  • Changes in vehicle-miles traveled
  • Hybrid gasoline or diesel trucks

• Electrification
  • Electric vehicle sales

• Non-energy sources
  • Mobile refrigerant global warming potential

• Low-carbon fuels (Upstream emissions in Minnesota)
  • Biofuels
  • Electricity
Vehicle Fuel Economy

- Fuel economy standards for light-duty vehicles have 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 Vehicle-Miles Traveled

• There are many ways to reduce 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 1% by 2030 and 3% by 2050 (in light-duty vehicles only)
• 100x50 Scenario
  • Reductions of 3% by 2030 and 5% by 2050 (in light-duty vehicles only)
Electric Vehicle Sales
Light-duty automobiles

- Example from light-duty automobiles*
- Reference
  - Follows EIA AEO expected sales (8.9% by 2030, 16% by 2050)
- 80x50 Scenario
  - 40% of sales by 2030, 80% by 2050
- 100x50 Scenario
  - Ramps up quickly to 60% of new sales of EVs by 2030 and 100% by 2040

*Assumptions for all vehicle types in appendix
Example from heavy-duty trucks*
Heavy-duty trucks may take longer to electrify, so we included diesel hybrid vehicles for long-haul trucks and electric vehicles for shorter distances

Reference
- No change from status quo

80x50 Scenario
- 30% sales of diesel hybrid vehicles, 15% sales of electric vehicles by 2030

100x50 Scenario
- 50% sales of diesel hybrid vehicles, 15% sales of electric vehicles by 2030

*Assumptions for all vehicle types in appendix
Mobile refrigerants

• 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
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
## Key Scenario Assumptions by Scenario

<table>
<thead>
<tr>
<th>Measure</th>
<th>80x50 Scenario</th>
<th>100x50 Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2030</td>
<td>2050</td>
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<tr>
<td><strong>Fuel Economy Standards</strong></td>
<td>Included 2021-2026</td>
<td>Included 2021-2026</td>
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<tr>
<td><strong>LDV VMT Reductions</strong></td>
<td>1% below Reference</td>
<td>3% below Reference</td>
</tr>
<tr>
<td><strong>Light-duty vehicles</strong></td>
<td>40% sales of EVs</td>
<td>60% sales of EVs</td>
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<tr>
<td><strong>Medium-duty vehicles</strong></td>
<td>30% sales of hybrids</td>
<td>55% sales of hybrids</td>
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<tr>
<td></td>
<td>15% sales of EVs</td>
<td>25% sales of EVs</td>
</tr>
<tr>
<td><strong>Heavy-duty vehicles</strong></td>
<td>30% sales of hybrids</td>
<td>50% sales of hybrids</td>
</tr>
<tr>
<td></td>
<td>15% sales of EVs</td>
<td>30% sales of EVs</td>
</tr>
<tr>
<td><strong>Biofuels</strong></td>
<td>20% blend</td>
<td>60% blend</td>
</tr>
<tr>
<td></td>
<td>~35% reduction in CI relative to 2015</td>
<td>~50% reduction in CI relative to 2015</td>
</tr>
<tr>
<td><strong>Electricity</strong></td>
<td>70% carbon-free</td>
<td>90% carbon-free</td>
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<tr>
<td><strong>Mobile Refrigerants</strong></td>
<td>100% sales by 2035</td>
<td>100% sales by 2025</td>
</tr>
</tbody>
</table>
Total surface transportation emissions by scenario (PCA accounting)

- **Reference**
- **80x50**
- **100x50**

- 15% below 2005 levels
- 30% below 2005 levels
- 80% below 2005 levels
GHG Emissions by Sector
PCA Accounting

• **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
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
Next Steps
Next Steps

• Input and Feedback
  • We are looking for feedback today on included measures and draft results

• Modeling
  • E3 will run updated scenarios
  • Updated results will be presented publicly starting on May 31st
Appendix
## Key Drivers for Baseline Scenario

<table>
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<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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<td>Light-Duty Autos and Trucks</td>
<td>VMT</td>
<td>1% (2016-2025) 0.44% (2030-2050)</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>
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<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>
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## Reference Scenario Assumptions

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<th>Sector</th>
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<td>Federal Fuel Economy Standards</td>
<td>Included through 2020, not extended 2021-2026</td>
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<tr>
<td></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></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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<td>MDVs</td>
<td>MDV EV + Hybrid Sales</td>
<td>N/A</td>
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<td>MDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>HDVs</td>
<td>HDV EV + Hybrid Sales</td>
<td>N/A</td>
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<td>HDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
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<td>Buses</td>
<td>Electric Buses</td>
<td>N/A</td>
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<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</td>
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<td>Ethanol carbon intensity</td>
<td>Constant carbon intensity</td>
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<td>Biodiesel</td>
<td>20% biodiesel by 2018 (12.5% annual average)</td>
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<td>Biodiesel Carbon Intensity</td>
<td>Constant carbon intensity</td>
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<td>Electricity</td>
<td>Electricity</td>
<td>48% zero-carbon generation statewide, 20% decrease in carbon intensity by 2025</td>
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<td>RVs</td>
<td>Biofuels for RVs</td>
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<td>Motorcycles</td>
<td>Electric Motorcycles</td>
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<td>Mobile Refrigerants</td>
<td>Lower GWP Refrigerants</td>
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# 80x50 Scenario Assumptions

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<td>LDV EV Sales</td>
<td>40% sales by 2030, 60% by 2050</td>
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<td>LDV VMT growth</td>
<td>1% reduction (for whole state) by 2030, 3% by 2050</td>
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<tr>
<td>MDVs</td>
<td>MDV EV + Hybrid Sales</td>
<td>20% sales by 2030, 25% by 2050</td>
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<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>
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<td>HDV VMT growth</td>
<td>1.4% 2016-2050</td>
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<td>Buses</td>
<td>Electric Buses</td>
<td>50% sales by 2030, 80% by 2050 (of those 100% BEV)</td>
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<td>Bus VMT growth</td>
<td>1.4% 2016-2050</td>
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<td>Biofuels</td>
<td>Ethanol</td>
<td>20% blend by 2030, 60% by 2050</td>
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<td>Ethanol carbon intensity</td>
<td>Declining carbon intensity (58% improvement by 2030)</td>
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<tr>
<td></td>
<td>Biodiesel</td>
<td>20% blend by 2030, 60% by 2050</td>
</tr>
<tr>
<td></td>
<td>Biodiesel Carbon Intensity</td>
<td>Declining carbon intensity (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, 60% 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>
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</table>
# 100x50 Scenario Assumptions

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<td>LDVs</td>
<td>Federal Fuel Economy Standards</td>
<td>Extended through 2026</td>
</tr>
<tr>
<td></td>
<td>LDV EV Sales</td>
<td>100% by 2040</td>
</tr>
<tr>
<td></td>
<td>LDV VMT growth</td>
<td>3% reduction (for whole state) by 2030, 5% by 2050</td>
</tr>
<tr>
<td>MDVs</td>
<td>MDV EV + Hybrid Sales</td>
<td>20% sales by 2030, 30% by 2050</td>
</tr>
<tr>
<td></td>
<td>MDV VMT growth</td>
<td>1.4% 2016-2050</td>
</tr>
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<td>HDVs</td>
<td>HDV EV + Hybrid Sales</td>
<td>80% sales by 2030, 100% by 2050</td>
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<td>HDV VMT growth</td>
<td>1.4% 2016-2050</td>
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<tr>
<td>Buses</td>
<td>Electric Buses</td>
<td>100% sales by 2040 (of those 100% BEV)</td>
</tr>
<tr>
<td></td>
<td>Bus VMT</td>
<td>1.4% 2016-2050</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Ethanol</td>
<td>20% blend by 2030, 100% by 2050</td>
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<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>
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<td>Biodiesel Carbon Intensity</td>
<td>Declining carbon intensity to carbon-neutral fuels by 2050</td>
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<tr>
<td>Electricity</td>
<td>Electricity</td>
<td>100% zero-carbon generation statewide (emission factor goes to zero by 2050)</td>
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<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 2035 have low-GWP refrigerant</td>
</tr>
</tbody>
</table>
Zero Emission Vehicle Sales
Light Duty Autos

Electric Vehicle Sales: Light Duty Autos
- 100x50
- 80x50
- Reference

Stock of Light Duty Autos: Reference
- Reference Gasoline
- Reference Diesel
- PHEV
- Electric Vehicle

Stock of Light Duty Autos: 80x50

Stock of Light Duty Autos: 100x50

5/20/2019
Zero Emission Vehicle Sales

Light Duty Trucks

Stock of Light Duty Trucks: Reference

Stock of Light Duty Trucks: 80x50

Stock of Light Duty Trucks: 100x50

5/20/2019 mndot.gov
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

5/20/2019
mndot.gov
Zero Emission Vehicle Sales
Heavy Duty Vehicles

Electric and Hybrid Vehicle Sales: Heavy Duty Trucks

Stock of Heavy Duty Trucks: 80x50

Stock of Heavy Duty Trucks: Reference

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

Electric Vehicle Sales: Buses

Stock of Bus: 80x50

Stock of Bus: Reference

Stock of Bus: 100x50

5/20/2019 mndot.gov
Air Pollution from Surface Transportation
Statewide Emissions

### Particulate Matter (PM10)

<table>
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<tr>
<th>Year</th>
<th>Reference</th>
<th>80x50</th>
<th>100x50</th>
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</thead>
<tbody>
<tr>
<td>2030</td>
<td>Emissions of Particulates PM10 in 2030</td>
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</tr>
<tr>
<td>2050</td>
<td>Emissions of Particulates PM10 in 2050</td>
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</tbody>
</table>

### Nitrogen Oxides (NOx)

<table>
<thead>
<tr>
<th>Year</th>
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<th>80x50</th>
<th>100x50</th>
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<tr>
<td>2030</td>
<td>Emissions of Nitrogen Oxides in 2030</td>
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<tr>
<td>2050</td>
<td>Emissions of Nitrogen Oxides in 2050</td>
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### Volatile Organic Compounds (VOCs)

<table>
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<th>100x50</th>
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<tbody>
<tr>
<td>2030</td>
<td>Emissions of Non Methane Volatile Organic Compounds in 2030</td>
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<tr>
<td>2050</td>
<td>Emissions of Non Methane Volatile Organic Compounds in 2050</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reference Scenario Results
Table Discussion

• Go to the table of your preferred transportation decarbonization strategy
  • Transit/Electric Transit/Heavy Duty
  • Community Design/Planning
  • Electric Vehicles
  • Biofuels & Other Low Carbon Fuels

• Facilitators will record group discussion on flip chart, one question per sheet
Are there specific assumptions you would change?
What seems too aggressive or not aggressive enough?
What are you most excited about?
Do the initial results reflect what you envisioned? Why or why not?
Are the results realistic?
Do you have any other feedback that hasn’t been addressed thus far?
Closing Thoughts & Next Steps

• Follow along with this effort at http://www.dot.state.mn.us/us/sustainability/pathways.html
  • Presentations
  • Webinar information
  • Outreach meetings

• Contact Tim Sexton with questions or comments
  • Timothy.sexton@state.mn.us
  • O: 651-366-3622 | C: 206-427-4949
Thank you again!

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