Impact of Michigan Transportation Fuel Scenarios on Air Quality and Health

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Summary

This study quantifies air quality and health impacts from accelerated adoption of electric vehicles (EVs) and low-carbon fuels for Michigan's vehicle fleet. To conduct this analysis, three emission inventories are constructed: 1) a Baseline inventory reflecting current (2022-2023) transportation and electricity sector emissions, 2) a Reference Case reflecting anticipated changes to the vehicle fleet and electricity sector by 2035, and 3) a "Midpoint" Scenario inventory reflecting accelerated adoption of EVs and low-carbon fuels. We calculated emission source reductions associated with each scenario and used the U.S. EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) to quantify particulate matter concentration changes and associated health impacts.[1]

Relative to the 2023 Baseline, both the 2035 Reference Case and the 2035 Midpoint scenario demonstrated reduced levels of health-damaging air pollutants contributing to ambient fine particulate matter. COBRA-calculated health benefits for the 2035 Reference Case Scenario ranged between $631 – $1,595 million annually. The 2035 Midpoint Scenario achieved 25% higher benefits, between $791 – $1,998 million annually. Air pollution is unequally borne by Black and Hispanic communities. For the Midpoint Scenario, 90% of benefits occur in 18 counties (ranging from $5.3 – $755M annually) that are home to 90% of Michigan's non-White population.

This research was funded by Great Plains Institute with additional financial support from the McKnight Foundation.

Background

Michigan's transportation and electricity sectors accounted for 26.2% and 28.5% of the State's 2020 greenhouse gas (GHG) emissions, respectively, as reported by U.S.EPA's State GHG Emissions and Removals.[2] Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOC) pollutants are known to deteriorate air quality and adversely impact health. On-road vehicles are responsible for 38% of NOx and 19% of VOC reported in U.S. EPA's National Emissions Inventory (NEI).[3] Electricity generation was responsible for 14% of 2017 NEI reported NOx. Sulfur Dioxide (SO_2), Ammonia (NH_3), and particulate matter ($PM_{2.5}$) also contribute to air quality and health impacts and are included in this studies' emission inventories.

Stakeholder initiatives in Michigan have aimed to decarbonize the State's transportation fuel mix through the accelerated adoption of electricity (EV vehicles) and increasing reliance on lower carbon-intensity transportation fuels. As part of these efforts, fuel inventory projections were modeled for which the Holloway Group has developed corresponding emission inventories. These inventories were used to assess air quality and health impacts using the COBRA tool. A schematic for the emission inventory construction is shown in Figure 1 below.

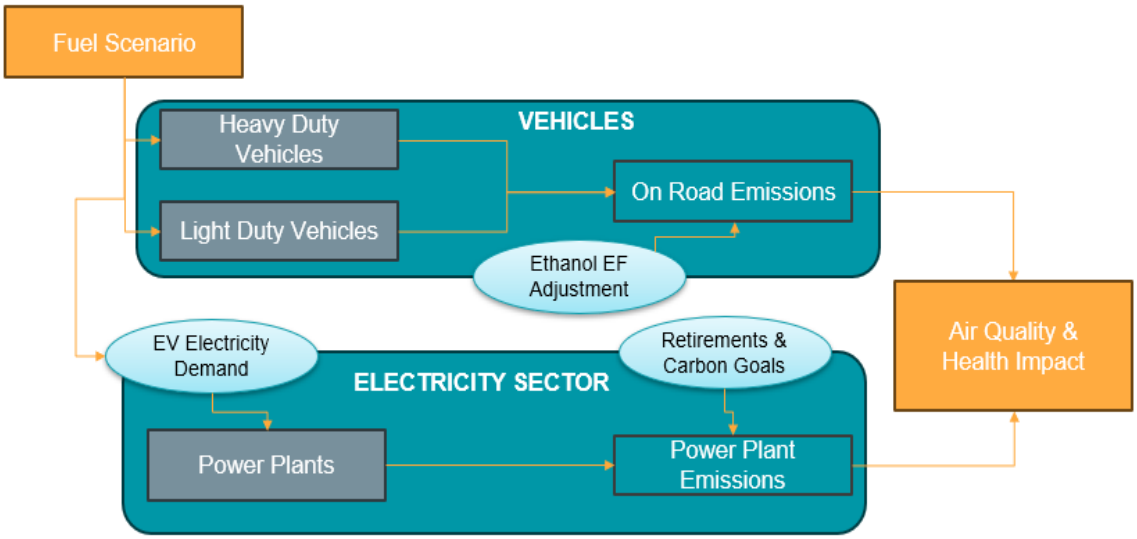

Figure 1. Scenario-based emission inventory construction for air quality and health impacts comparison. The EPA COBRA Tool is used to calculate the impacts of: 1) the 2035 Reference Case relative to the 2023 Baseline, and 2) the 2035 Midpoint Case relative to the 2023 Baseline.

Methods

Scenario fuel volumes were supplied by the Great Plains Institute and Horizon Climate Group for the Baseline, Reference Case, and Midpoint scenarios. For the purposes of air quality modeling, fuel volumes were characterized as illustrated in Figure 2. Corresponding to these fuel inputs, we calculate county-level emissions for on-road vehicles and power plants responding to increased demand from EVs.

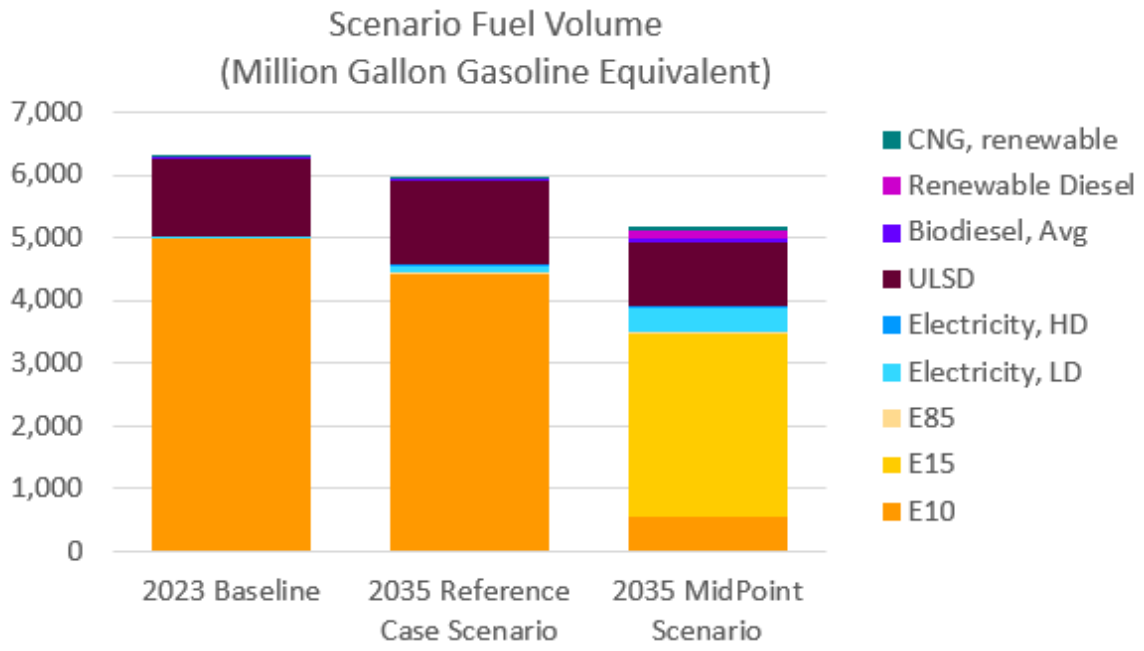

Figure 2. Scenario Fuel Volumes

Emission rates for on-road vehicles are based on the U.S. EPA's MOtor Vehicle Emission Simulator (MOVES) model, reflecting the forward-looking evolution of Michigan's vehicle fleet.[4] County-level tail-pipe emission rates are calculated from the corresponding vehicle-fuel combinations in MOVES .[1] Starting from the MOVES-derived emission rates, vehicle emission factors are adjusted to reflect scenario-specific ethanol blend level impacts, using a weighted average of factors reported by Kazemiparkouhi, et. al (in figures 3 – 6).[5] The result was a decrease in vehicle emission rates for the Midpoint scenario for NO_x (1.1%), $PM_{2.5}$ (7.2%), and VOC (3.5%) applied uniformly across all vehicle types.

While electric vehicles (EVs) do not contribute to on-road emissions, EV contribution to electricity demand must be considered. To do so, power plant emissions resulting from

[1] MOVES forecasts that tail-pipe emissions decline through 2032 as the vehicle fleet evolves toward increasingly advanced emission controls.

EV charging are assumed to occur in Michigan only. Baseline electricity sector emissions are based on 2022 emission levels reported by U.S. EPA Clean Air Markets Program Database[6]**Error! Bookmark not defined.** For the 2035 Reference Case and 2035 Midpoint scenarios, power plant emission sources were removed from the inventory where a scheduled retirement was reported prior to 2035.[7] The remaining (non-retiring) power plant sources were further scaled downwards, commensurate with Michigan Healthy Climate Plan goals for GHG reduction (2035 levels) for the 2035 Reference Case and 2035 Midpoint scenarios.[1]

RESULTS

Following the methods described above, three emission inventories are constructed: 1) a 2023 Baseline inventory reflecting current (2022-2023) transportation and electricity sector emissions, 2) a 2035 Reference Case reflecting anticipated changes to the vehicle fleet and electricity sector by 2035, and 3) a 2035 Midpoint Scenario inventory reflecting accelerated adoption of electric vehicles and low-carbon fuels. The Baseline emissions inventory, illustrated in Figure 3, is constructed using the COBRA 4.1 2023 Emissions baseline. Substitutions are made to update electricity sector emissions to 2022 reported levels (highlighted blue in Figure 3) and to update transportation sector emissions to correspond to the EPA MOVES model projections for 2023 (highlighted orange in Figure 3).

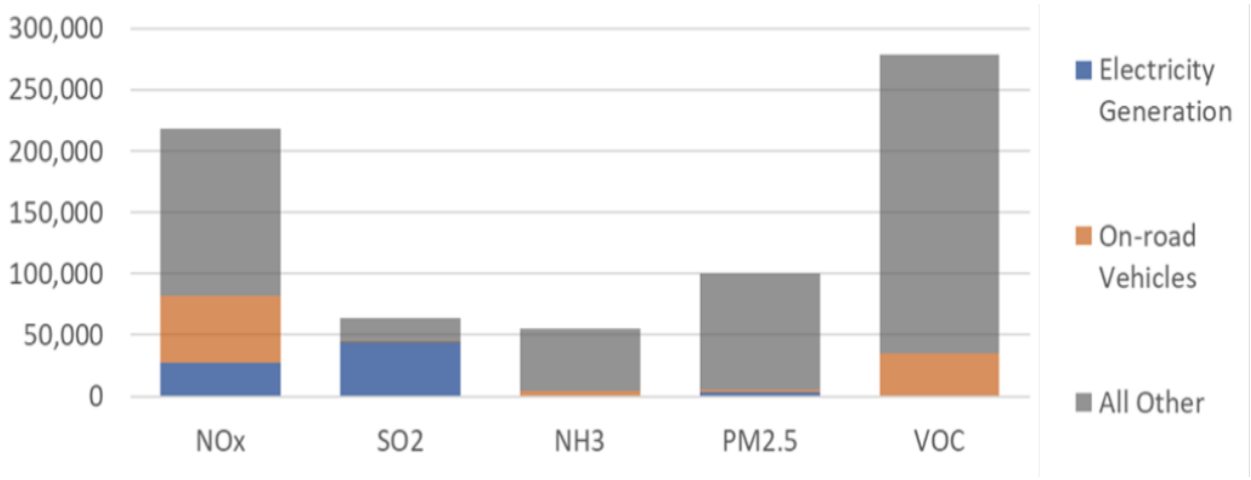

Figure 3. Baseline emissions inventory using the COBRA 4.1 2023 Emissions baseline, with substitutions to update electricity sector emissions to 2022 reported levels and to update transportation sector emissions to correspond to the EPA MOVES model projections for 2023. Excludes natural sources.

Figure 4 illustrates the emission source reductions associated with the 2035 Reference Case and 2035 Midpoint Scenarios, relative to the Baseline. In the 2035 Reference Case, emissions changes reflect advancements in IC engine pollution control, announced power plant retirements, and electricity sector decarbonization goals. The 2035 Midpoint Scenario further adjusts the Reference Case to reflect accelerated EV and low-carbon fuel adoption. Both the Midpoint and Reference Case scenario demonstrate emission reductions for electricity and transportation sectors. The Midpoint Scenario has slightly fewer reductions in the electricity sector, as is expected due to higher EV penetration. When both on-road vehicles and electricity emissions are accounted for, the Midpoint Scenario achieves: 4,851 fewer tons NO_x, 16 more tons SO_2, 753 fewer tons NH_3, 377 fewer tons $PM_{2.5}$, and 5,958 fewer tons VOC.

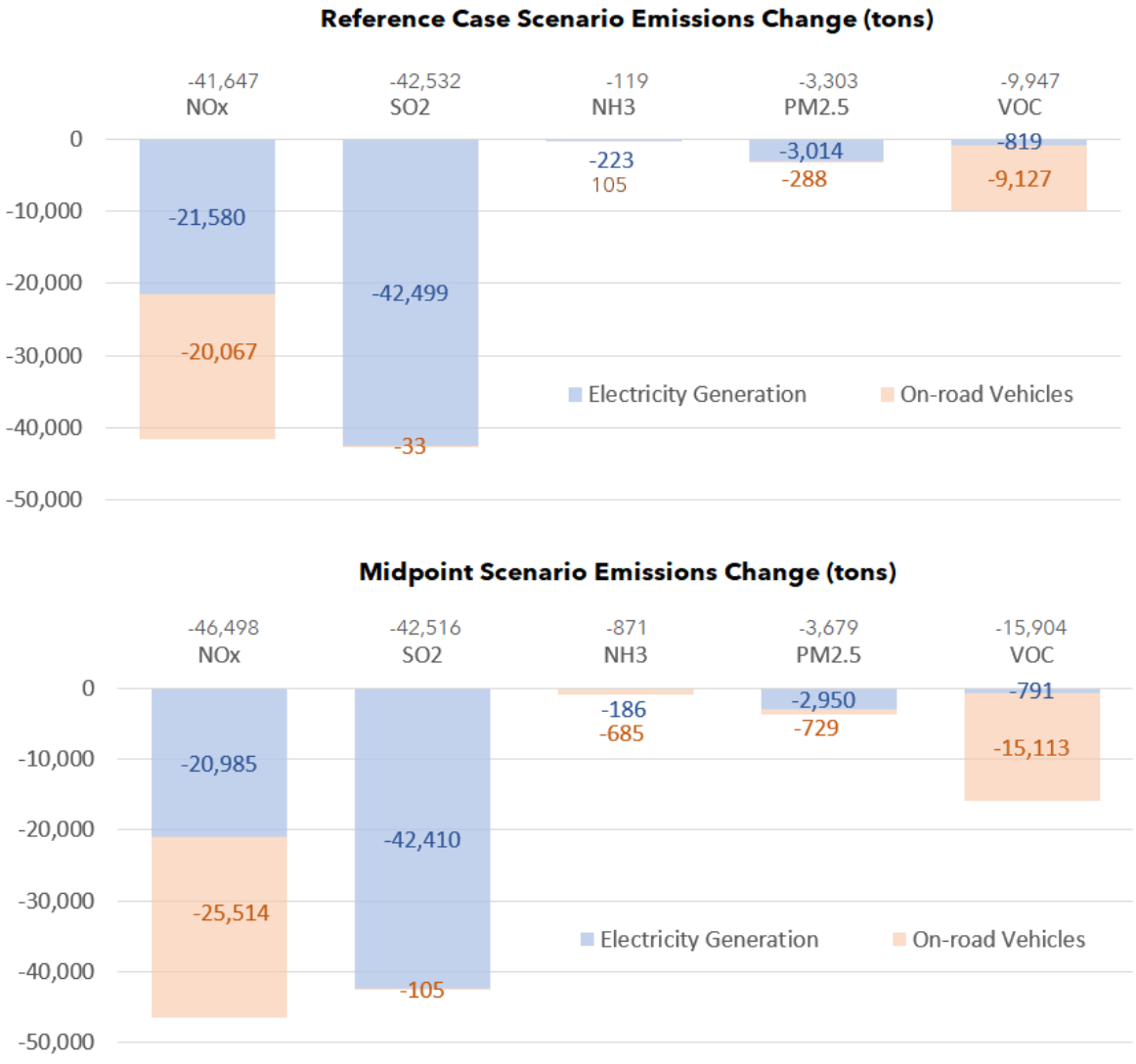

Figure 4. Calculated emission change from 2023 Baseline for 2035 Reference Case and 2035 Midpoint Scenarios

The U.S. EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) was used to quantify the resulting reduction in particulate matter concentration.[8] County-level emission source reductions associated with the Reference Case and Midpoint scenarios were evaluated, relative to the 2023 Baseline Scenario. COBRA calculated an 0.053 ug/m^3 reduction in atmospheric $PM_{2.5}$ concentration (county-level average) for the Reference Case and an 0.062 ug/m^3 (17% larger) reduction for the Midpoint Scenario. COBRA is a "reduced-form" air quality model, meaning it simplifies many of the complex dynamics of emission sources, atmospheric chemistry, and human health. The model approximates atmospheric chemistry and transport to estimate reductions in ambient $PM_{2.5}$ concentrations. COBRA then uses epidemiological "C-R functions" to translate the $PM_{2.5}$ concentration reductions into county-level health improvements.

COBRA estimates the economic value associated with adverse health impacts resulting from annual $PM_{2.5}$ exposure, of which the value of avoided premature mortality is the largest contributor. High and low estimates of avoided premature death are derived using two sets of assumptions reflecting low sensitivity (Krewski et al. 2009) and high sensitivity (Lepeule et al. 2012) to ambient $PM_{2.5}$.[9,10] Although only ambient $PM_{2.5}$ is modeled, this includes primary $PM_{2.5}$ associated with emissions, as well as secondary $PM_{2.5}$ formed from gas-phase emissions of SO_2 and NOx, secondary organic aerosols formed from VOC emissions, and NH_3. It should be noted that additional health outcomes are associated with exposure to SO_2 and NO_x, and that NO_x and VOC contribute to ground-level ozone formation. These additional air pollution health risks may be significant for asthma and other health outcomes, but they are not included in COBRA and omitted from the health estimates in this report.

Table 1. COBRA Reported PM2.5 Health Benefits (Avoided Annual Incidents)

	Mortality	Work-Loss Days	Restricted Activity Days	Respiratory Symptoms & Asthma Exacerbation	Annual Benefit ($Million / year)
Reference Scenario	64 - 144	1,304,485	38,659	3,632	631 - 1595
Midpoint Scenario	80 - 180	1,641,684	48,642	4,556	791 - 1998

COBRA reported health impacts are reported in Table 1. Ranges reported indicate high values using a 3% discount rate and low values using a 7% discount rate.[2] The total annual health benefits represent the impact achieved at full implementation, and as such are reported as future values (COBRA Version 4 results are in 2017$). COBRA reported the 2035 Reference Case Scenario to achieve between $631 – $1,595 annual

[2] EPA's Guidelines for Preparing Economic Analyses recommend developing an upper and lower bound for economic benefits. This analysis used the COBA-supplied options for an upper bound using a 3% discount rate and a lower bound using a 7% discount rate.

health benefits. COBRA reported the 2035 Midpoint Scenario to achieve 25% higher benefits, between $791 – $1,595 annually. Financial benefits from reduced mortality comprised 98-99% of total health benefits.

The geographic distribution of COBRA emission benefits is illustrated in Figure 6. All counties experience air quality improvement in the Midpoint scenario. Higher population areas realize higher benefits because more people experience cleaner air. 90% of benefits occur in 18 counties (range of $5.3 – $755M/yr). The remaining 65 counties average between $1.2 - $3.1M/yr in annual benefits.

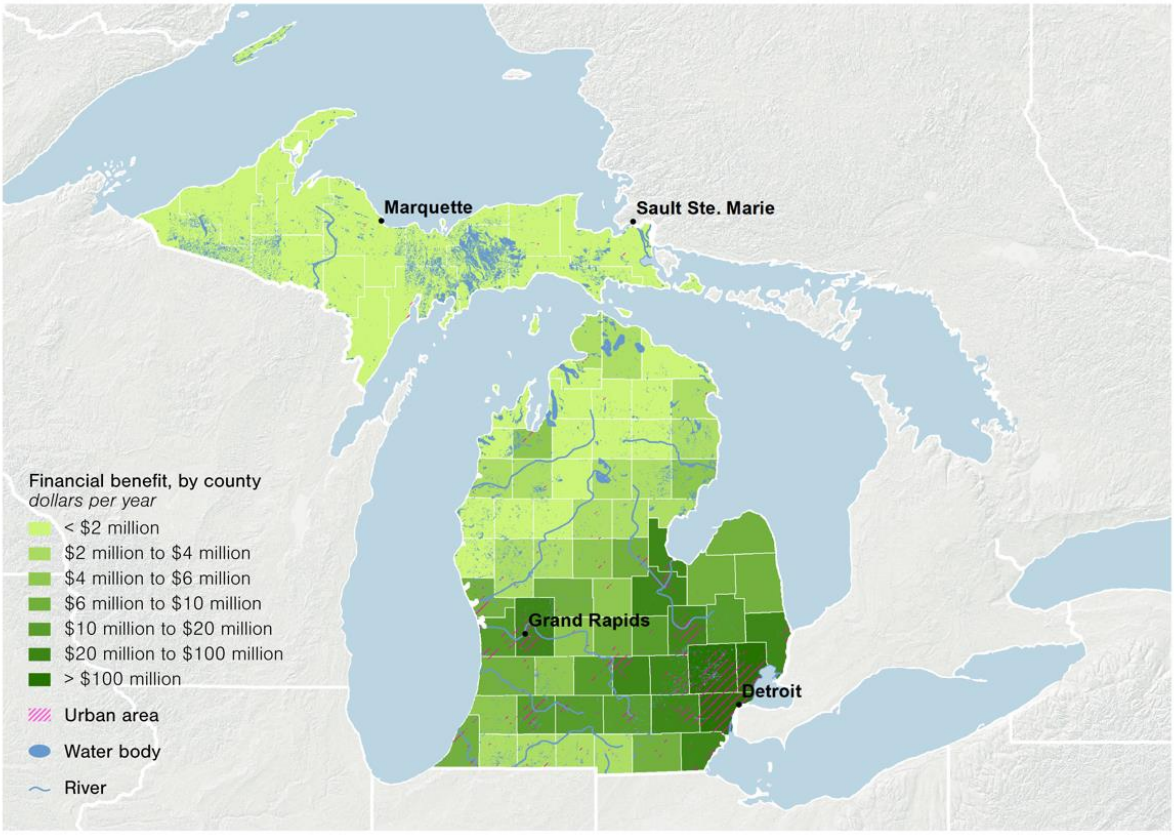

Figure 6. Midpoint Scenario distribution of COBRA-calculated high-benefits (3% discount rate). County-level benefits distribution is a function of emission reductions and population. (Figure authored by Elizabeth Abramson, Horizon Climate Group.)

Conclusion

This study quantifies air quality and health impacts resulting from scenarios that accelerate adoption of low-carbon fuels for Michigan's vehicle fleet. The Holloway Group calculated emission source reductions associated with each scenario and used the U.S. EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) to quantify the resulting reduction in particulate matter concentration and associated health impacts. Relative to the 2023 Baseline, both the 2035 Reference Case and the 2035 Midpoint scenario reduced levels of health-damaging air pollutants contributing to ambient fine particulate matter. The 2035 Reference Case Scenario achieved between $631 – $1,595 annual health benefits. The 2035 Midpoint Scenario achieved 25% higher benefits, between $791 – $1,595 annually. Air pollution is unequally borne by Black and Hispanic communities. For the Midpoint Scenario, 90% of benefits occur in 18 counties, ranging from $5.3 – $755M annually. These same counties are home to 90% of Michigan's non-White population.

Acknowledgement

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