



March 17, 2021

The Honorable Carrie Ruud
Chair, Senate Environment and Natural
Resources Policy and Legacy Finance Committee
3233 MN Senate Building
95 University Avenue West
St. Paul, MN 55155

The Honorable Bill Ingebrigtsen
Chair, Senate Environment and Natural
Resources Finance Committee
3207 MN Senate Building
95 University Avenue West
St. Paul, MN 55155

The Honorable David Senjem
Chair, Senate Energy and Utilities
Finance and Policy Committee
3401 MN Senate Building
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The Honorable Rick Hansen
Chair, House Environment and Natural
Resources Policy & Finance Division
407 State Office Building
100 Rev. Dr. Martin Luther King Jr. Blvd.
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The Honorable Jamie Long
Chair, House Energy and Climate Finance
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The Honorable Patricia Torres Ray
Ranking Minority Member, Senate Environment
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The Honorable Nick Frentz
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The Honorable Foug Hawj
Ranking Minority Member, Senate Environment
and Natural Resources Policy and
Legacy Finance Committee
2201 MN Senate Building
95 University Avenue West
St. Paul, MN 55155

RE: CORRECTION - Biennial Greenhouse Gas Emissions Reduction Report

Dear Committee Chairs and Ranking Minority Members:

The Minnesota Department of Natural Resources has requested a minor correction be made in the methodology portion of the 2021 Biennial Greenhouse Gas Emissions Reduction Report, originally submitted to the Legislature on January 14, 2021.

Committee Chairs and Ranking Minority Members
CORRECTION - Greenhouse Gas Emissions Reduction Report
Page Two
March 17, 2021

The requested correction is to the discussion of forest carbon sequestration on page 19 of the Report. The text, upon original publication, read "Given the many unknowns about the future of our forests, we estimate a higher probability that carbon stored in the forest will remain there for about 25 years." We have changed the report to read "Given the many unknowns about the future of our forests, we estimate forest carbon residence times as they vary by forest, age, type, and carbon pool." The updated Report contains an editorial comment noting that the document was revised after its original publication.

If you have any questions regarding this correction, please contact Frank Kohlasch, MPCA Climate Director, at Frank.Kohlasch@state.mn.us or at 651-757-2500.

Sincerely,

A handwritten signature in blue ink that reads "Greta Gauthier". The signature is fluid and cursive, with a horizontal line extending to the right.

Greta Gauthier
Assistant Commissioner for Legislative and Intergovernmental Relations
Minnesota Pollution Control Agency

Enclosure

GG:FC:cbg



January 14, 2020

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Legacy Finance Committee
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RE: Biennial Greenhouse Gas Emissions Reduction Report

Dear Committee Chairs and Ranking Minority Members:

Enclosed, please find the 2021 Biennial Greenhouse Gas Emissions Reduction report by the Minnesota Department of Commerce and the Minnesota Pollution Control Agency (MPCA), submitted pursuant to Minn. Stat. § 216H.07 subd 3.

Committee Chairs and Ranking Minority Members
Greenhouse Gas Emissions Reduction Report
Page Two
January 14, 2021

This report discusses the trend of Minnesota's greenhouse gas emissions from 2005 to 2018, as they relate to the Next Generation Energy Act goals.

If you have any questions regarding this report, please feel free to contact Frank Kohlasch, MPCA Climate Director, at Frank.Kohlasch@state.mn.us or at 651-757-2500.

Sincerely,



Grace Arnold
Commissioner (Temporary)
Minnesota Department of Commerce



Laura Bishop
Commissioner
Minnesota Pollution Control Agency

Enclosure

AR:GG:FC:cbg



REPORT TO THE
LEGISLATURE
MARCH 2021



Greenhouse gas emissions inventory 2005-2018

Biennial report to the Minnesota Legislature
outlining greenhouse gas emissions sources
and trends.

m MINNESOTA

Pollution Control Agency
Department of Commerce



Greenhouse gas emissions inventory: 2021 report to the Minnesota Legislature

Minnesota's not on track to meet its goals

In 2007, Governor Tim Pawlenty signed the bipartisan Next Generation Energy Act into law, setting statutory goals to reduce greenhouse gas (GHG) emissions by 15% from 2005 levels by 2015, 30% by 2025, and 80% by 2050. Minnesota missed its goal in 2015, and currently is not on track to meet future goals, either. Since 2005, overall GHG emissions overall have declined just eight percent.

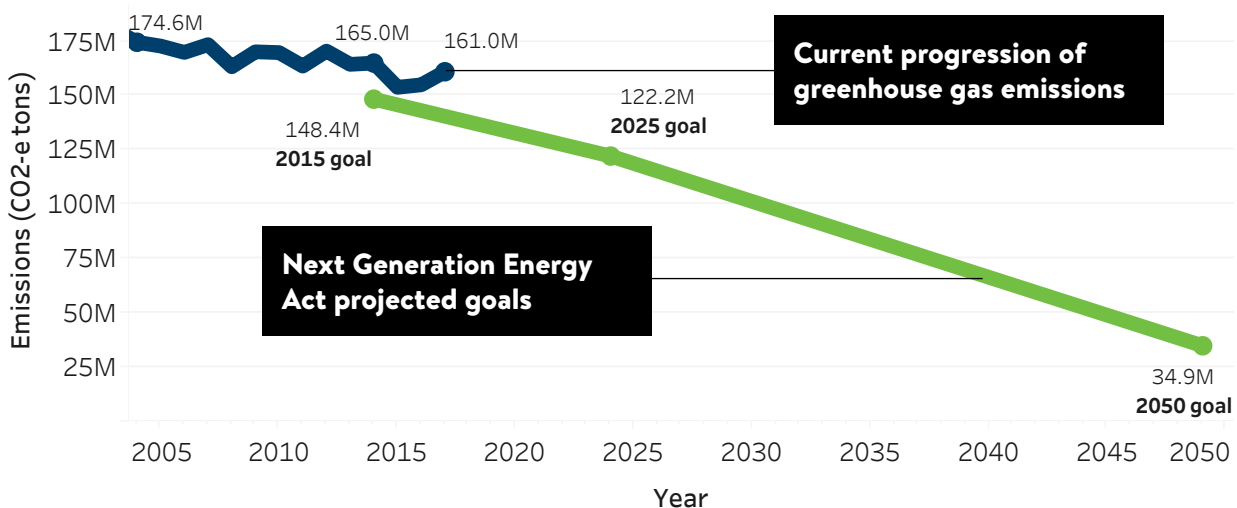


Figure above: Minnesota's greenhouse gas emissions (million tons CO₂-e), 2005-2018, compared to the 2015, 2025, and 2050 goals of the Next Generation Energy Act.

Minnesota's largest sources



Transportation

Largest source of emissions in Minnesota, and most pressing need for swift and decisive action. Emissions decreased by about 7% since 2005, but have mostly leveled off in recent years. This sector will require ongoing, focused effort to reach our goals.



Electricity generation

Positive progress toward our goals has been concentrated here. Electricity generation is the only sector currently on track to meet our Next Generation Energy Act goals. Emissions decreased by 29% since 2005.

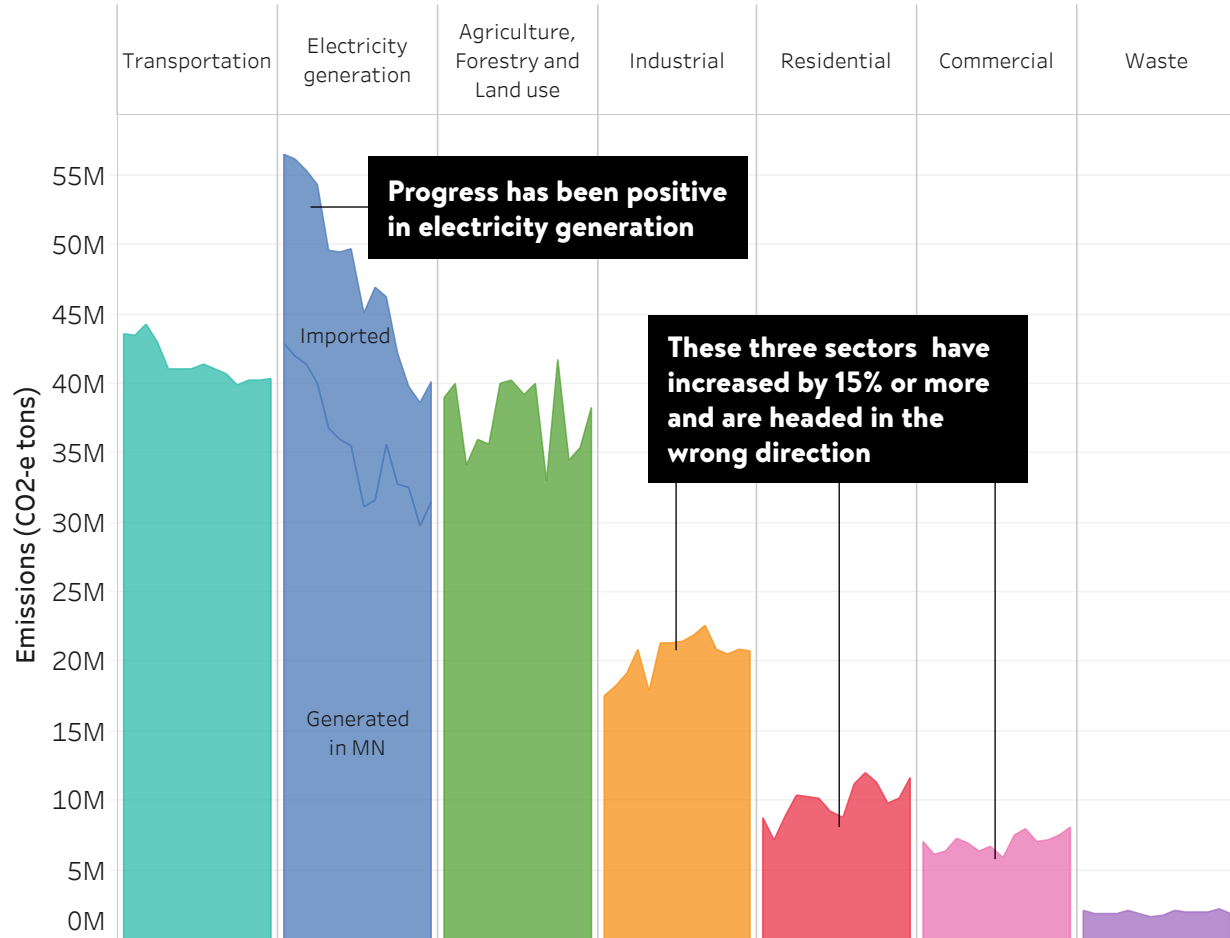


Ag/forestry/land use

It's complicated. Some emissions from crop and animal agriculture have increased by more than 10% since 2005, but forest regrowth has helped offset these increases. Overall emissions decreased by just 2% since 2005, and remain highly variable year-to-year.

The big picture

The positive progress Minnesota has seen so far has been concentrated in the electricity generation sector. Since 2005, all other sectors have seen only modest reductions or emission increases. Industrial, residential, and commercial have all increased by 15% or more and are heading in the wrong direction.



Emission change 2005 to 2018	Transportation	Electricity generation	Agriculture, Forestry and Land use	Industrial	Residential	Commercial	Waste
	-3.27M	-16.40M	-0.76M	3.22M	2.83M	1.05M	-0.24M
	-7%	-29%	-2%	18%	32%	15%	-11%

Legislative charge

Minn. Stat. § 216H.02 Greenhouse gas emissions control.

Subd. 1. Greenhouse gas emissions-reduction goal. It is the goal of the state to reduce statewide greenhouse gas emissions across all sectors producing those emissions to a level at least 15 percent below 2005 levels by 2015, to a level at least 30 percent below 2005 levels by 2025, and to a level at least 80 percent below 2005 levels by 2050. The levels shall be reviewed based on the climate change action plan study.

Minn. Stat. § 216H.07 Emissions-reduction attainment; policy development process.

Subd. 3. Biennial report. (a) By January 15 of each odd-numbered year, the commissioners of commerce and the Pollution Control Agency shall jointly report to the chairs and ranking minority members of the legislative committees with primary policy jurisdiction over energy and environmental issues the most recent and best available evidence identifying the level of reductions already achieved and the level necessary to achieve the reductions timetable in section 216H.02. (b) The report must be in easily understood nontechnical terms.

Authors

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This report was edited to correct a statement about forest regrowth in March 2021.

Minnesota Pollution Control Agency

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This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

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Introduction

Minnesota's climate is changing rapidly, and these changes – driven largely by human activities that cause emissions of greenhouse gases (GHGs) – are affecting our health, communities, economy and livelihoods, and natural resources.

This emissions inventory summarizes what we know about GHG emissions in Minnesota, including the major sources and trends over time. Tracking GHG emissions and identifying their sources are two important ways that state government can help Minnesotans understand our changing climate and respond accordingly.

Collecting and analyzing data helps policy makers at the local, regional, and state level identify opportunities and challenges for reducing GHG emissions. Having a clear picture of Minnesota's GHG emissions trends and sources helps all Minnesotans understand whether we are making progress toward our goals, and where more efforts are needed.

Evaluating greenhouse gas emissions

GHGs are gases that warm the atmosphere and surface of the planet. Human activity has been increasing the amount of GHGs in the atmosphere, leading to changes in the earth's climate. The primary GHGs are carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄), sulfur hexafluoride (SF₆), and two classes of compounds called hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). Carbon dioxide is the most abundant of these GHGs, and has had the largest effect on our climate. Other GHGs are emitted in smaller amounts, but can trap heat more effectively than carbon dioxide, and some stay in our atmosphere for a very long time.

Global warming potential (GWP) is a relative measure of how much heat a GHG traps in the atmosphere (Table 1).¹ In order to compare different emissions and pollutants, we use the effect of carbon dioxide on our climate as a common reference. In this report, emissions are reported as carbon dioxide-equivalent (CO₂-e) tons, meaning emissions are stated in terms that reflect their GWP.

¹ GWP is a measure of how much energy the emissions of one ton of a gas will absorb over a given time period, relative to how much energy the emission of one ton of carbon dioxide can absorb. These numbers use the standard 100-year time period for comparison. The GWP of carbon dioxide is one, as it is compared to itself. One ton of nitrous oxide, on the other hand, can absorb 265 to 298 times as much energy as one ton of carbon dioxide over a 100-year period.

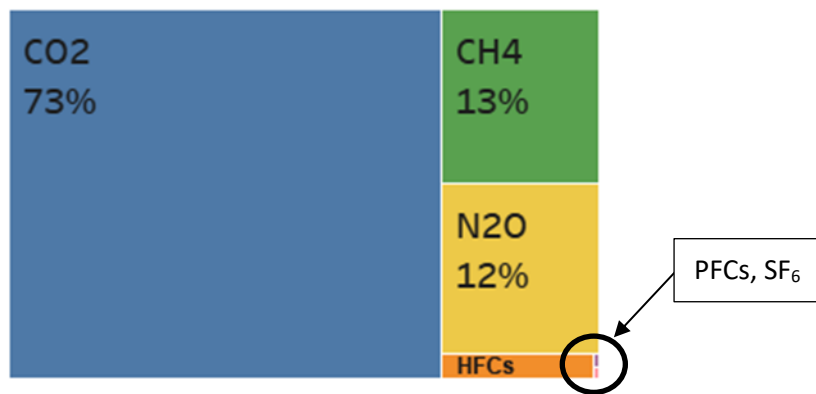
Table 1. Primary GHGs, their global warming potentials, and their persistence in Earth’s atmosphere.

Greenhouse gas	Global warming potential	Persistence in Earth’s atmosphere
Carbon dioxide (CO ₂)	1	Variable, up to thousands of years
Nitrous oxide (N ₂ O)	265-298	114 years
Methane (CH ₄)	28-36	12 years
Sulfur hexafluoride (SF ₆)	22,800	3,200 years
Hydrofluorocarbons (HFCs)	Up to 14,800	Up to 270 years
Perfluorocarbons (PFCs)	Up to 12,200	2,600 to 50,000 years

Source: U.S. EPA, Overview of Greenhouse Gases, <https://www.epa.gov/ghgemissions/overview-greenhouse-gases>

In Minnesota, carbon dioxide emissions account for nearly three quarters of total GHG emissions in the state, followed by methane and nitrous oxide (Figure 1).

Figure 1. GHG emissions in Minnesota, by type, measured in CO₂-e tons (2018).



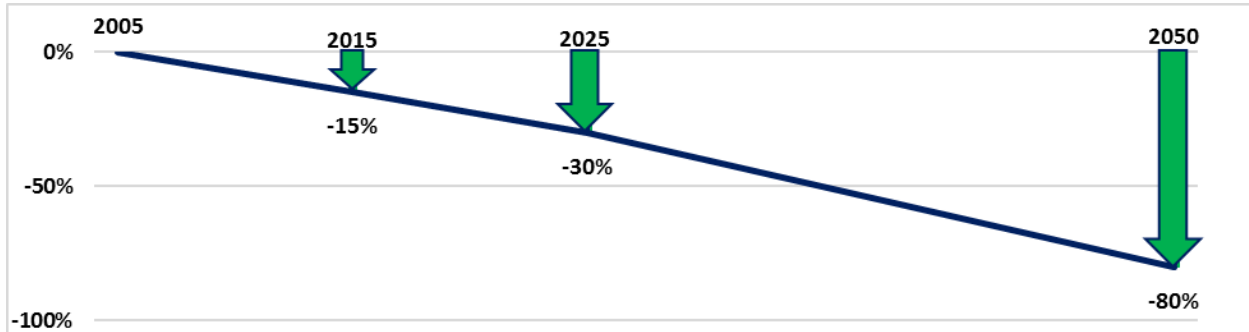
GHGs come from a variety of sources:

- Fossil fuel combustion is responsible for most carbon dioxide emissions in Minnesota and the U.S. The majority of fossil fuels used today are for generating electricity and fueling vehicles.
- Animal agriculture is responsible for the majority of methane emissions in Minnesota. Methane is also emitted from the anaerobic decomposition of organic material.
- Over 50% of nitrous oxide emissions are caused by agricultural nutrient management practices, including the application of fertilizer and subsequent mineralization.
- The majority of hydrofluorocarbon emissions are from refrigerants, such as in air conditioning in vehicles and buildings.
- Perfluorocarbons and sulfur hexafluoride account for a small portion of GHG emissions and are emitted as the result of technical applications, like semiconductor manufacturing and electricity transmission.

Tracking Minnesota's emission reduction progress

In 2007, the Minnesota Legislature passed the Next Generation Energy Act, which set interim and long-term goals for reducing GHG emissions in the state: a 15% reduction by 2015, a 30% reduction by 2025, and an 80% reduction by 2050, from a 2005 baseline (Figure 2).²

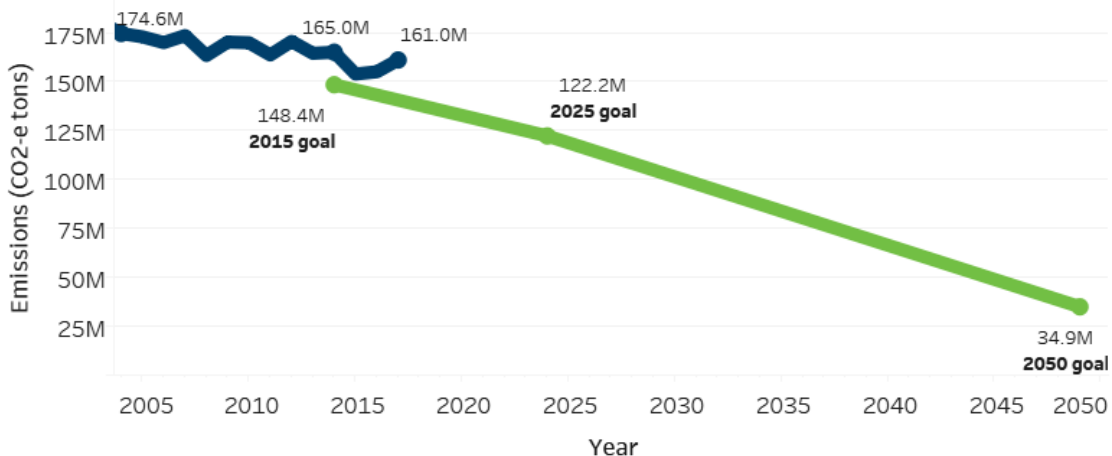
Figure 2. Next Generation Energy Act goals for GHG emissions reductions (Minn. Stat. § 216H.02).



As we reported previously, Minnesota did not reach the Next Generation Energy Act goal of reducing emissions by 15% by 2015. Between 2005 and 2018, Minnesota has only seen a modest decrease in GHG emissions: an approximately 8% reduction overall. This modest overall decline is largely driven by significant emissions reductions from electricity generation. Other sectors have seen emission increases or small emission decreases relative to the 2005 baseline.

In the shorter term, GHG emissions in Minnesota increased between 2016 and 2018, putting us further off track (Figure 3). Although some fluctuation in emissions year to year is normal, the trend in emissions indicates Minnesota will not meet its Next Generation Energy Act goals without significant action in all sectors.

Figure 3. Minnesota's GHG emissions (million tons CO₂-e), 2005-2018, compared to the Next Generation Energy Act goals



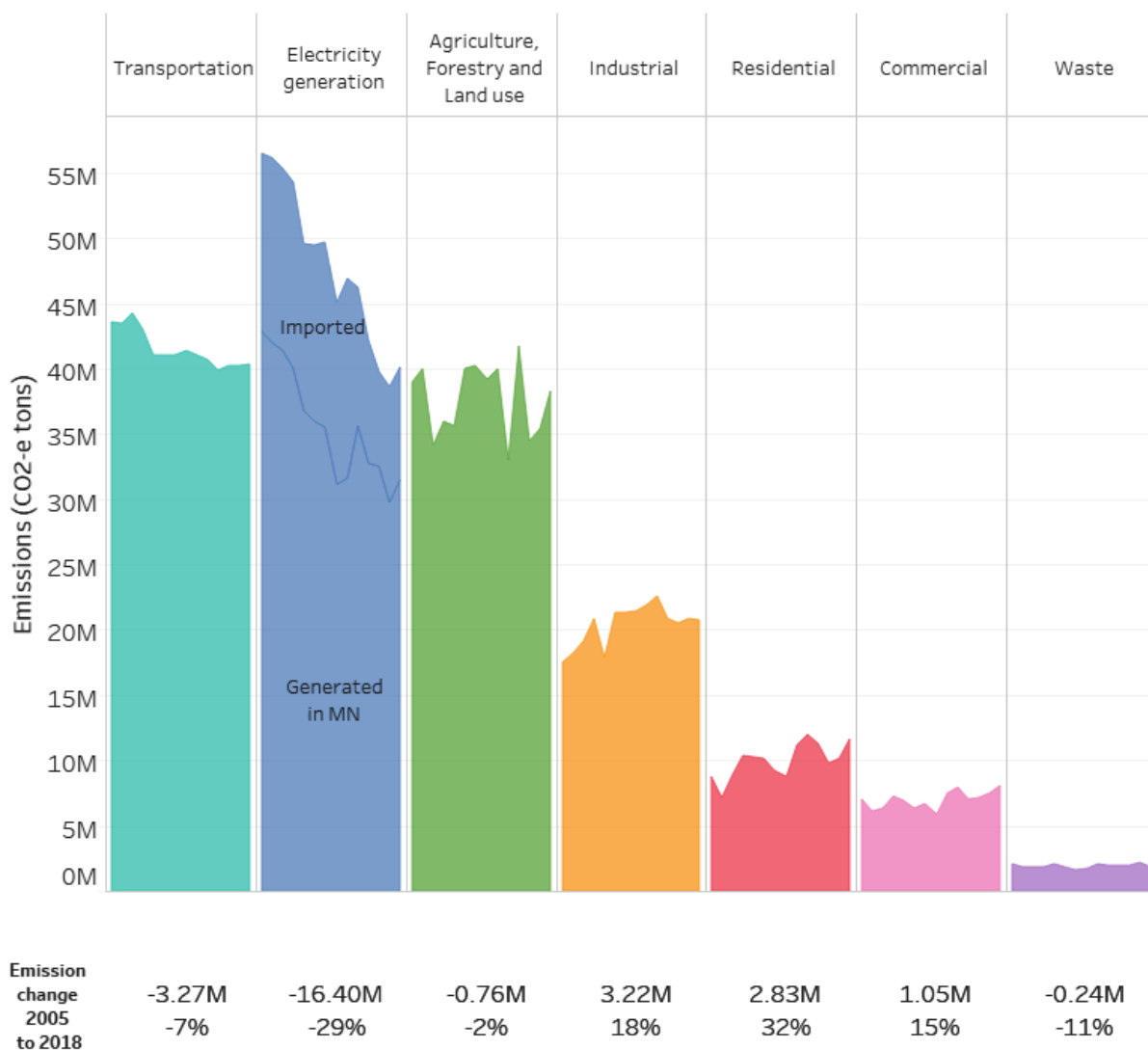
² Data revisions and changes in methodology can cause the baseline to change, but continuity is provided when making relative year-to-year emissions comparisons.

Greenhouse gas emissions across sectors

This section outlines GHG emissions changes across seven economic sectors in Minnesota: transportation, electricity generation, agriculture and forestry, industrial, residential, commercial, and waste.

The three economic sectors with the highest greenhouse gas emissions – transportation, electricity generation, and agriculture, forestry, and land use – accounted for over 70% of total emissions in 2018. Despite significant reductions in the electricity generation sector and modest decreases in emissions from the transportation sector, emissions from other sectors have generally stagnated, or worsened, from 2005 to 2018 (Figure 4).

Figure 4. Minnesota’s GHG emissions across economic sectors, 2005-2018. The dark line in the column for the electricity generation sector represents the division between emissions from electricity generated in Minnesota (below the line) and emissions from net imports of electricity (above the line).



Transportation

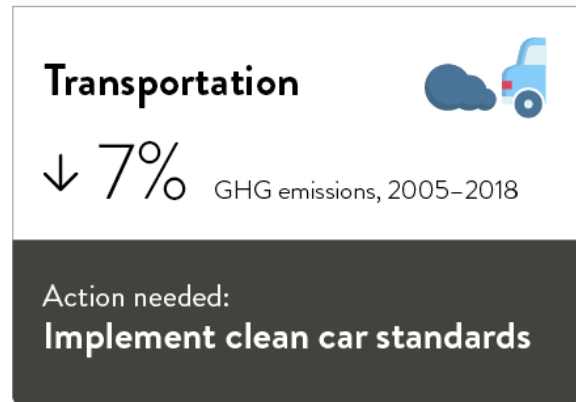
The transportation sector is currently the largest source of GHG emissions in Minnesota, accounting for about one quarter of the total GHG emissions in the state. GHG emissions from transportation have decreased by about seven percent since 2005, but reductions have leveled off since 2016.

Emissions sources in the transportation sector include:

- On-road vehicles
- Airplanes and other aviation equipment
- Trains
- Vehicle air conditioning units
- Natural gas transmission pipelines

Our personal choices have an impact on emissions, especially when it comes to how we move around. Within the transportation sector, more than 70% of emissions come from passenger vehicles, light-duty trucks (includes SUVs), and medium- to heavy-duty trucks.

More stringent vehicle tailpipe emissions standards at the federal level – implemented between model years 2012 and 2020 – helped lower vehicle GHG emissions generally, but the consumer trends of owning larger vehicles and driving them more miles is preventing more significant emissions reductions in this sector. Since the federal GHG tailpipe emissions standards finalized in 2020 for light- and medium-duty passenger vehicles are now less stringent and will allow more emissions, it's more important than ever that Minnesota takes action to reduce GHG emissions from transportation.



Electricity generation

Electricity generation is the second largest source of GHG emissions. Despite the incremental increase in emissions in recent years, Minnesota continues to see excellent progress in reducing emissions from the electricity sector due to expanded use of renewable energy.

GHG emissions from electricity generation come from several sources, including:

- Burning fossil fuels to directly generate electricity
- Methane from coal storage
- The breakdown of organic matter in the sediments found in hydroelectric reservoirs
- Carbon dioxide from flue-gas desulfurization
- Sulfur hexafluoride from electricity transmission and distribution

Prior to 2016, the electricity generation sector was the largest source of GHG emissions in Minnesota. Starting in 2016 and continuing through 2018, emissions from electricity generation (including imported



and in-state generation) are a close second to emissions from the transportation sector.³ Emissions from electricity generation decreased between 2016 and 2017, then increased in 2018.

A series of factors likely contributed to the increase of electricity generation emissions from both natural gas and coal use in 2018. These include the impacts of a warmer summer and slightly cooler winter than usual, which could have resulted in higher electricity demands; rapid economic growth in the output of goods and services; and rapid consumer spending on goods and services.

As required by the Next Generation Energy Act, this report measures total GHG emissions from electricity generation, which includes both emissions from electricity generated at facilities within the state (in-state generation) as well as electricity used here in Minnesota that is generated outside of our state borders (imported). Emissions from in-state generation fell about 27% from 2005 to 2018, reflecting efforts by Minnesota’s electric utilities to create a cleaner, lower carbon electrical grid. Emissions from imported electricity are higher on a kilowatt-hour basis, as neighboring states haven’t reduced their emissions as much as Minnesota. The amount of electricity that we import continues to decrease as we generate more of our electricity in Minnesota, which reduces the amount we estimate as imported.

Since 2005, overall emissions from the electricity generation sector (including both in-state generation and imported electricity) have declined 29%. The significant decrease relative to the 2005 baseline is largely due to reductions in the amount of coal burned to generate electricity and the increased use of renewable energy.

Agriculture and forestry

Agriculture and related practices in Minnesota are responsible for the most in-state emissions of both nitrous oxide and methane, two potent GHGs that have a significantly higher GWP than carbon dioxide. Year to year, overall emissions from the agriculture and forestry sector can be highly variable, but emissions of nitrous oxide and methane have both increased since 2005.

Emissions sources in the agriculture and land use sector include:

- Livestock
- Animal feedlots
- Manure
- Fertilizer
- Crop cultivation practices
- Anaerobic decomposition of organic material
- Related fuel combustion of off-road implements, like tractors and combines



³ Comparisons between sectors depend on the categories and boundaries chosen and the methods used to estimate emissions. See the appendix for further discussion of methods.

Nitrous oxide emissions from crop agriculture increased by approximately 12% from 2005 to 2018. The largest source of nitrous oxide emissions in Minnesota is nutrient management, which includes fertilizer use, mineralization, and runoff. The increase from 2005 to 2018 was due to modest increases in emissions from a variety of agricultural sources, including nutrient management practices, crop residues, deposition, and manure application.

During the same time period, methane emissions from animal agriculture increased by about 15%. Animal agriculture is the largest source of methane emissions in Minnesota, specifically from manure management and cattle digestion. An increase in the total head of cattle in Minnesota, relative to 2005, can help explain increased methane emissions, as well as increased manure amounts, more ruminants in Minnesota herds, and increased emissions from wild rice. Our lakes, rivers, and reservoirs are another large source of methane emissions, which occur from the breakdown of organic matter in sediments.

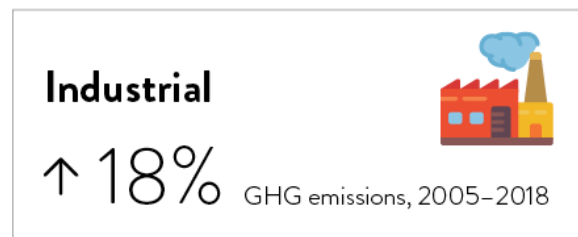
Compared to the 2005 baseline, emissions from the agriculture and forestry sector have decreased about two percent overall, but annual emissions were highly variable due to the method used to estimate carbon sequestered in forest regrowth.

Carbon sequestration in forest regrowth is a significant offset in this sector, as forests can act as carbon sinks, or storage. Carbon is sequestered in our forests as they grow. Although there is not a stable or predictable trend, the carbon stored in Minnesota's forests between 2005 and 2018 increased, which helped offset GHG emissions increases from crop and animal agriculture. This sector is the focus of continued research and development to better understand how to estimate emissions and offsets from forest growth and forest changes in Minnesota more accurately.

Industrial

Emissions sources in the industrial sector include:

- Fuel combustion
- Taconite processing
- Petroleum refining
- Magnesium casting
- Lead recycling
- Peat mining
- Industrial wastewater treatment
- Solvent use
- Manufacturing of steel, glass, insulating foam, and semiconductors



CO₂-e emissions data for individual sources with Minnesota Pollution Control Agency (MPCA) air permits are available on the MPCA website at <https://www.pca.state.mn.us/air/permitted-facility-air-emissions-data>.

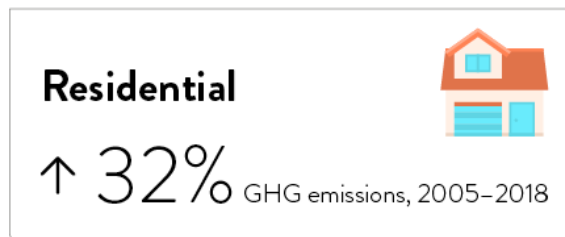
Within the industrial sector, coal use has continued to decline steadily. Natural gas use has increased since 2005, but has remained relatively stable since 2010.

Relative to 2005, emissions from the industrial sector increased by about 3.2 million tons CO₂-e. Total energy use in the industrial sector peaked in 2014 and has declined slightly since then; however, 2018 emissions remain roughly 18% above the 2005 baseline. Though GHG emissions from this sector have plateaued in recent years, we are not seeing sufficient reductions to get Minnesota on track to meet our Next Generation Energy Act goals.

Residential

Emissions sources in the residential sector include:

- Fuel combustion for heating and in-home appliances, like water heaters or clothes dryers
- Fertilizer use
- Home-product use
- Food additives
- Refrigerant leakage from air conditioners and refrigerators



The residential sector does not include emissions from electricity use in residences.⁴ However, this category does include carbon stored in wood construction materials for periods long enough that the carbon is effectively removed from the atmosphere, or sequestered, which offsets some emissions from the residential sector.

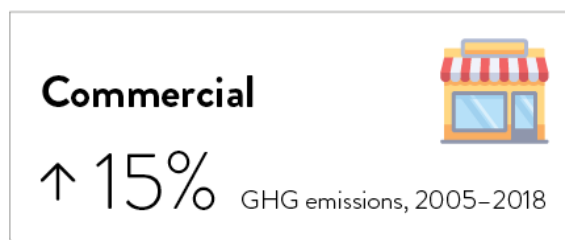
Relative to 2005, emissions from the residential sector were an alarming 32% above the 2005 baseline. The vast majority of that increase – accounting for a full 2 million tons CO₂-e – occurred between 2016 and 2018, likely due in part to both atypically cooler and warmer weather in 2018. Increasing GHG emissions indicate that this sector is heading in the exact opposite direction needed to make progress toward our Next Generation Energy Act goals.

Commercial

Emissions sources in this sector include:

- Fuel combustion
- Solvent use
- Medical N₂O emissions

Institutional emissions are counted in this sector as well.



Relative to 2005, emissions from the commercial sector were about 15% above the 2005 baseline. As in the residential sector, this increase was likely driven, at least in part, by building heating and cooling demands caused by a warmer summer and slightly cooler winter than usual in 2018. As with GHG emissions from the residential sector, the trend for commercial emissions is headed in the wrong direction.

⁴ Emissions from electricity use are included in the electricity generation sector rather than categorized by type of consumer and divided into each sector.

Waste

Of the seven sectors we study, the waste sector is responsible for the least amount of GHG emissions annually in Minnesota.

Emissions sources in the waste sector include:

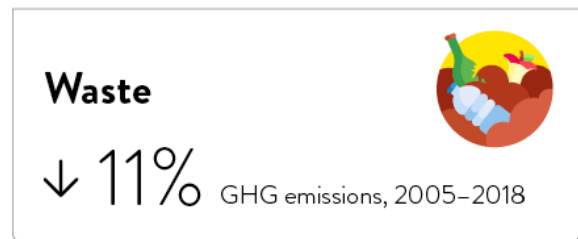
- Energy use in waste processing
- Incinerator fuels
- Waste incineration
- Methane from landfill gas and wastewater treatment

Carbon is stored or sequestered from the atmosphere as wood waste in demolition and construction landfills, which offsets other waste emissions. Sequestration of carbon in landfills has declined relative to 2005, leading to a lower emissions offset.

Compared to the 2005 baseline, GHG emissions from the waste sector have decreased by about 11%. Gradually decreasing methane emissions from landfills, and lower nitrous oxide emissions, are driving this trend. Decreasing methane emissions are due to a combination of factors, primarily the aging of waste in open landfills – older waste emits less methane as the organic fraction decomposes and becomes more stable – and gas capture technologies being used at closed landfills. As the administrator of the state’s closed landfill program, the MPCA has been working to address methane emissions from these facilities.

Nitrous oxide emissions are decreasing primarily because of a reduction in the application of biosolids.

More information about managing closed landfills can be found on the MPCA website at <https://www.pca.state.mn.us/waste/closed-landfill-program>.



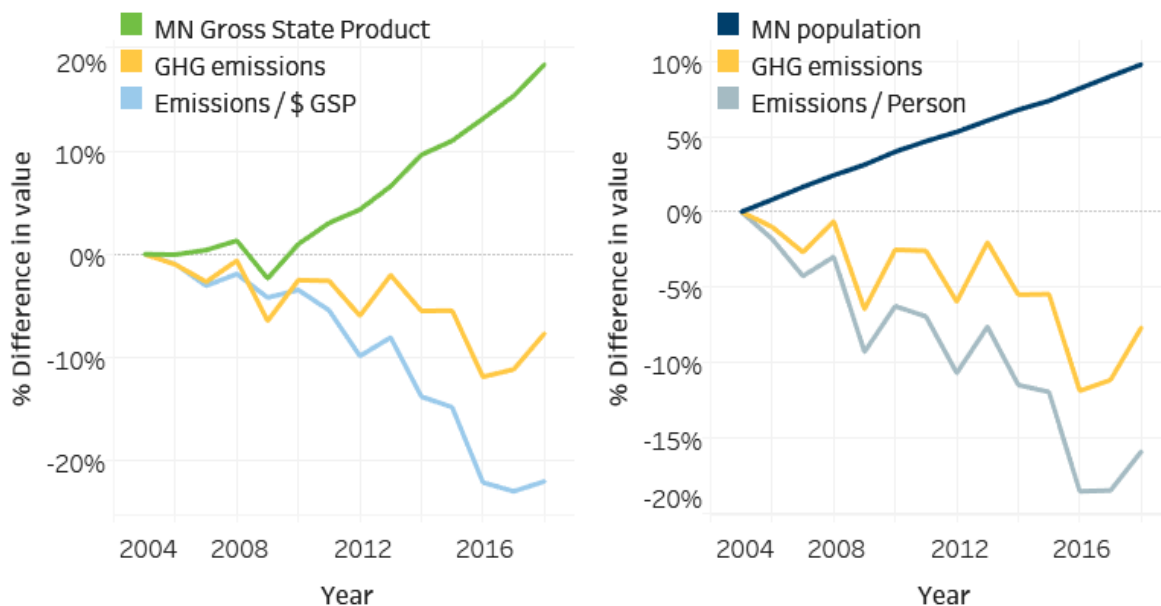
Greenhouse gas emissions and our economy

Measuring the amount of GHG emissions compared to other economic indicators is one way to understand how GHG emissions relate to our economy. Trends show that Minnesota has begun to disconnect our economic growth from our GHG emissions. Minnesota's gross state product has grown since 2005 while GHG emissions have generally decreased, demonstrating that our state economy can grow without necessarily increasing GHG emissions (Figure 5a).

Similarly, Minnesota's generally decreasing GHG emissions shows that our population can grow while reducing our GHG emissions. This is the case with per capita GHG emissions. Though the population in Minnesota is increasing, there is a net decrease in how many emissions each individual is responsible for creating, on average (Figure 5b).

Figure 5a (left). Minnesota's GHG emissions per dollar gross state product (GSP), 2005-2018.

Figure 5b (right). Minnesota's GHG emissions, per capita, 2005-2018.



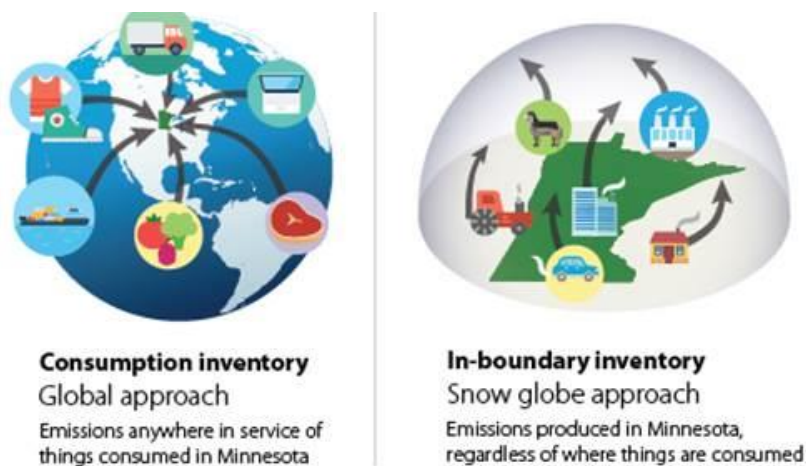
Consumption-based emissions inventory

The MPCA developed its first consumption-based emissions inventory (CBEI) for GHG emissions in 2012. In contrast to our standard in-boundary emissions inventory, which only considers emissions within the boundaries of Minnesota, a CBEI includes all emissions, wherever they occur, that are associated with the consumption of goods and services in Minnesota (Figure 6).

Emissions that occur out of state but are associated with production, transport, or disposal of things consumed in Minnesota are included in our CBEI, but not in our standard inventory.

Emissions that occur within Minnesota but are associated with goods and services that are exported outside the state for consumption elsewhere are included in our standard inventory, but not included in our CBEI.

Figure 6. Consumption based global inventory versus in-boundary inventory



The differences in these emissions accounting methods are important to consider for two reasons: consumption largely drives emissions, and GHGs are globally mixed pollutants (they have the same global impact regardless of the geographic source).

In 2012, our in-boundary inventory of GHG emissions totaled approximately 154 million tons of CO₂-e while our CBEI totaled around 147 million tons. Since our in-boundary inventory slightly exceeds our consumption-based inventory, Minnesota is a net exporter of emissions. That is, the emissions associated with goods and services produced in Minnesota but consumed elsewhere exceed the emissions associated with imported goods and services. Minnesota's high carbon intensity industries, namely its agricultural sector, is a likely explanation for this finding.

Closer analyses help us better understand what types of consumption in Minnesota contribute the most GHG emissions. For example, we have broken down consumption-based emissions by types of goods and services (food, electronics, material goods, health care services), by consuming institution (households, government, firms) and by the phase in the life-cycle of all that we consume (production, pre-purchase transportation, use, disposal). A full presentation of these results is available online at <https://www.pca.state.mn.us/air/consumption-related-emissions>. Generally, the use of vehicles and appliances (heating, cooling, cooking, washing) contributed the most to consumption-based emissions, followed by the production of food and beverages.

A better understanding of the links between the consumption of specific goods and services and GHG emissions is fundamental for Minnesotans to understand and reduce the climate impact of their purchases, and for the state to design effective GHG reduction policies. Conducting and reporting a CBEI can clarify the relationship between consumption and GHG emissions, and help Minnesota households, businesses, and policy makers chart a path to more sustainable consumption patterns.

Our path forward

Climate change is an existential threat that puts everyone in Minnesota at risk. More frequent mega-rains, warming winter temperatures, and increasing extreme heat events are already affecting our livelihoods, our natural resources, and our health and well-being. Communities, farms, and industry are all facing threats to infrastructure, economic stability, and our environment. More information about the impacts of climate change in communities across Minnesota can be found at <https://climate.state.mn.us/local-impacts>.

Although we are all affected by our changing climate, the negative impacts of climate change are not experienced equally and can vary depending on race, gender, geography, or socio-economic status, among other factors. Some communities bear a disproportionate burden of climate change's harmful effects, including communities of color, lower-income communities, and indigenous communities in Minnesota. Policies that do not reflect considerations of equity can exacerbate these existing disparities in Minnesota. As part of our commitment to environmental justice, MPCA and other state agencies will continue to focus on equitable policies and strategies to reduce GHG emissions and increase community resilience in the face of climate change.

Climate Change Executive Order

Minnesota is taking bold action to reduce GHG emissions and meet or exceed our Next Generation Energy Act goals. On December 2, 2019, Governor Walz signed Executive Order 19-37, or the Climate Change Executive Order, reiterating the size and scope of the climate crisis and the need for innovative climate solutions to protect and prepare Minnesotans.

The Climate Change Executive Order brings a new, clearer emphasis for state agencies to work together and created a new Climate Change Subcabinet, comprised of 15 state leaders and chaired by the commissioner of the MPCA, Laura Bishop. The subcabinet was established to identify and advance policies and strategies that will:

- Put Minnesota back on track to meet or surpass our GHG reduction goals and achieve 100% clean energy by 2050
- Enhance climate resiliency of Minnesota's natural resources, working lands, and communities and assist state agencies, businesses, and local communities to prepare for climate change impacts that cannot be avoided

The Climate Change Executive Order encourages enhanced public engagement around these complex issues. The subcabinet is specifically tasked with promoting equitable policy solutions that can reduce current disparities in Minnesota, ensure a just transition for impacted workers and communities, and encourage green economic development and job creation.

In 2020, the subcabinet began meeting regularly and organized multiple working groups to advance their work. These working groups include action teams to address green jobs and the economy, natural and working lands, the power sector and buildings, resiliency and adaptation, and transportation. To learn more about the subcabinet, visit <https://climate.state.mn.us/subcabinet>.

The executive order also established the Governor's Advisory Council on Climate Change. Fifteen members were named to the advisory council in September 2020, including civic and community leaders, individuals with experience in business, agriculture, conservation, environmental protection, and other stakeholders. The advisory council will work alongside the subcabinet to identify

opportunities for, and barriers to, policies and strategies to reduce GHG emissions and increase climate resiliency. Meet the members and learn more about the advisory council's work at <https://climate.state.mn.us/advisory-council>.

Tackling Minnesota's largest sources of greenhouse gas emissions

A cleaner, low-carbon transportation future

The transportation sector represents our greatest opportunity to reduce climate-changing pollution in Minnesota, and is the sector with the most pressing need for swift and decisive action. Practical strategies that achieve emissions reductions while ensuring that Minnesotans have access to reliable and varied transportation options, including different kinds of vehicles and modes of transportation, include:

- Adopting clean car standards to ensure Minnesotans have access to the cleanest vehicles available
- Advancing the use of electric vehicles (EVs) and building out EV infrastructure
- Promoting cleaner fuels, including biofuels
- Supporting community-led efforts to reduce emissions, including the increased use and availability of public transit and alternative modes of transportation, like walking and biking

In 2019, the MPCA began a new rulemaking process to adopt two clean car standards, known as the Clean Cars Minnesota rule, to reduce tailpipe GHG emissions from vehicles and improve the availability of EVs in Minnesota. If adopted, the rule would reduce GHG emissions and other harmful air pollution from new light- and medium-duty vehicles and require auto manufacturers to deliver more zero-emissions vehicles, like battery EVs and plug-in hybrids, for sale in Minnesota. If adopted, the rule would apply to new vehicles beginning with model year 2025. Learn more about the Clean Cars Minnesota rulemaking at <https://www.pca.state.mn.us/air/clean-cars-mn>.

MPCA is leveraging funds from Minnesota's share of the national Volkswagen settlement to advance EVs and build a statewide EV charging network. In 2021, MPCA plans to invest up to \$2.6 million for the installation of up to 38 additional fast-charging stations across Greater Minnesota, extending the existing EV charging highway corridor network by more than 2,500 miles. Grant applications for this funding closed in November 2020, but more information about this project and the expanded EV corridors can be found at <https://www.pca.state.mn.us/air/ev-fast-charging-corridor-grants>.

MPCA's Volkswagen grant programs also help businesses, local governments, and other organizations replace older, diesel-powered vehicles, school buses, and equipment with cleaner models, including electric. In 2020, Minnesota became the first state in the Midwest to launch an innovative, \$3 million pilot project that will fund up to ten new all-electric school buses in order to learn more about their performance and range in our climate.

To date, MPCA has invested more than \$4.5 million from the Volkswagen settlement in EV charging stations, and plans to spend the maximum amount allowed under the terms of the settlement on EV infrastructure to enable more Minnesotans to use this clean vehicle technology. Learn more about MPCA's investments in a cleaner transportation future at <https://www.pca.state.mn.us/vw>.

Also in 2019, Governor Walz signed Executive Order 19-35, which created the Governor's Council on Biofuels. The council will advise the Governor and state government on the potential role of biofuels in reducing GHG emissions, among other objectives, and suggest policies and budget proposals that would support farmers and rural communities as they work to produce biofuels. For more information on the

Governor's Council on Biofuels, visit <https://www.mda.state.mn.us/environment-sustainability/governors-council-biofuels>.

MPCA serves as an advisor and technical resource for a wide range of other transportation planning and funding efforts that support alternative modes of transportation like public transit, walking, and biking.

Supporting clean energy

Minnesota's work on clean energy shows we can reduce GHG emissions cost-effectively while meeting increasing energy needs from a growing economy. The electricity generation sector's steep reductions in GHG emissions in Minnesota have resulted from policies to reduce demand for electricity and shift generation to cleaner energy sources. These policies have worked in tandem with market forces that make many renewable resources more cost-effective than coal facilities.

In Minnesota and surrounding states, utilities continue to close coal plants and replace that power generation with a mix of renewables, supported by natural gas in cases of high demand. Several electricity generating facilities, especially those powered by coal, have either recently retired or are planned to be retired soon (Table 2).

Table 2. Remaining electric utility-owned coal-fired electricity generating units in Minnesota (as of December 2020).

Facility	Size (nameplate capacity, MW; rounded)	Status
Hibbing Public Utilities Commission		
Hibbing 3	10	Standby/backup: available for service but not normally used
Hibbing 5	20	Standby/backup: available for service but not normally used
Hibbing 6	6	Standby/backup: available for service but not normally used
Minnesota Power		
Boswell unit 3	365	Operating
Boswell unit 4	558	Operating
Taconite Harbor Energy Center unit 1	75	Standby/backup: available for service but not normally used
Taconite Harbor Energy Center unit 2	75	Standby/backup: available for service but not normally used
Otter Tail Power Company		
Hoot Lake 2	54	Operating, full retirement by 2021
Hoot Lake 3	75	Operating, full retirement by 2020
Xcel Energy		
Sherburne County 1	680	Operating, full retirement by 2026
Sherburne County 2	682	Operating, full retirement by 2023
Sherburne County 3	876	Operating, proposed retirement by 2030
Allen S King	511	Operating, proposed retirement by 2028

Recent and upcoming decisions in Minnesota utilities' integrated resource plans are expected to further reduce GHG emissions. The Minnesota Public Utility Commission's decision to update and adjust the external costs of carbon dioxide emissions imposed by utilities – referred to as the social cost of carbon – is another way that the state is contributing to GHG emissions reduction policies.

Agriculture plays a pivotal role in climate solutions

Minnesota can achieve emissions reductions from this sector by speeding the rate of adoption and increasing total acreage where best management practices (BMPs) are used, as many agricultural BMPs that protect water quality and build soil health also reduce GHG emissions.

Some of the more promising practices for reducing GHGs from agriculture include improved efficiency of nitrogen use through optimized fertilizer application rates and the timing and use of nitrification inhibitors, conservation cover, vegetative buffers along streams, changes in tillage, and cover crops. In 2019, MPCA released a report identifying the GHG emission reduction co-benefits of 21 different

agricultural BMPs, available at <https://www.pca.state.mn.us/air/agriculture-and-climate-change-minnesota>.

The MPCA and Minnesota Department of Agriculture (MDA) work together with agricultural producers and land stewards to find sustainable solutions for reducing GHG emissions and protecting our water, soil and wildlife, including through the Minnesota Agricultural Water Quality Certification program (MAWQC). Since the program began in 2013, more than 970 producers and over 685,000 acres have been certified. To learn more about MAWQC, visit <https://www.mda.state.mn.us/environment-sustainability/minnesota-agricultural-water-quality-certification-program>.

MPCA has also begun estimating GHG emissions for environmental assessment worksheets submitted for feedlot proposals. New or expanding feedlots with more than 1,000 animal units (500 in a sensitive area) are required to submit environmental assessment worksheets, which include a review of several factors, like potential for runoff, traffic changes, and air emissions, including hydrogen sulfide. More information on feedlot environmental assessments can be found at <https://www.pca.state.mn.us/water/feedlot-environmental-review>.

Preparing for, and adapting to, a changing climate

In addition to reducing GHG emissions, state action is needed to help communities prepare for, and adapt to, a changing climate. In 2018, the MPCA adopted a strategic goal focusing on climate adaptation, which spurred new action across agency programs to address emerging climate impacts for regulated parties and communities, evaluate existing rules and regulations, and work to increase community resilience. MPCA actively seeks funding for local governments to incorporate resilience into planning and infrastructure, and works with community partners to identify and reduce risks for climate-vulnerable populations and to implement adaptation best practices. To learn more about MPCA's climate adaptation efforts, visit <https://www.pca.state.mn.us/air/adapting-changing-climate>.

The takeaway: Swift action needed beyond the power grid

Minnesota has made important progress in reducing GHG emissions, but we are not on track to achieve our Next Generation Energy Act statutory goals. Since 2005, significant GHG emissions reductions from the electricity generation sector have driven overall emission trends downward, while emissions from other sectors have stagnated or even increased.

The improvement made in the electricity generation sector shows that smart climate policies and programs can and do reduce GHG emissions. Emissions from Minnesota's electricity generation sector will continue to decrease as our regional energy is increasingly produced from renewable sources. Now, we must accelerate the pace of progress by focusing on innovative policies and strategies in other sectors, especially transportation and our agricultural and working lands.

Together, Minnesotans can achieve significant emission reductions by supporting and promoting EVs, cleaner fuels (such as biofuels), and accessible and affordable public transportation and alternative options. Minnesota can be a leader in the rapid and equitable adoption of EVs, but more public and private entities need to make conscious decisions when replacing fleets and personal vehicles. Retailers also need to support the sale and availability of a wide range of EV options for consumers.

There are also significant opportunities for GHG emissions reductions from our agricultural sector. Without the support of farmers, foresters, and other stewards of our working lands and natural areas, we will not be able to reach our GHG emissions reduction goals. Farmers are one of the foundational

pillars of Minnesota's economy, and they can play a pivotal role in increasing our climate resilience. Our croplands and forests are already being altered by climate change; if we don't work together to adapt to these changes and prevent further damage, all Minnesotans lose.

Under Executive Order 19-37, Minnesota has a renewed mandate to establish and accelerate policies that will put us back on track to meet or exceed our Next Generation Energy Act goals and achieve greater resiliency in the face of climate change, but we need immediate, additional effort from our policy makers, workforce, and neighbors to effectively protect and prepare Minnesota.

Appendix: Methodology

Greenhouse gas emission inventory

A technical support document published in 2012 with the emissions report for 1970-2008 provides a more detailed discussion on the calculation methodology and is available on the MPCA website at <https://www.pca.state.mn.us/air/greenhouse-gas-emissions-minnesota-0>.

Only emissions that occur within the geographical borders of the state are estimated, with two exceptions – net imports of electricity into the state to meet Minnesota demand and emissions from the combustion of aviation fuel purchased in Minnesota, but not necessarily combusted within Minnesota air space.⁵

GHG inventory protocols require that evaluation of state-level GHG emissions take into account photosynthetically-removed carbon dioxide stored in biomass in forests, soils, landfills, and structures. Carbon storage and emissions from forests and agricultural soils are tracked separately from the emissions inventory because it is difficult to estimate specific sources within the larger estimate of carbon flux. Storage of carbon in forest regrowth is incorporated into the agriculture and forestry sector using a discounted storage term of 25 years. Long-term storage of wood-carbon in residential structures and demolition and construction landfills is included in statewide GHG emission totals because it is more certain that the materials will remain as carbon stores for a long time.

Emissions are estimated for all years from 1970 to 2018, though presented here in an abbreviated timeline. With a few exceptions, the methods used to develop these estimates are derived from the following sources:

- U.S. Environmental Protection Agency (2020) Inventory of U.S. greenhouse gas emissions and sinks: 1990-2018.
- California Air Resources Board, California Climate Action Registry, International Council for Local Environmental Initiatives, Local Governments for Sustainability, and The Climate Registry (2010) Local government operations protocol for the quantification and reporting of greenhouse gas emissions inventories, version 1.1.
- Intergovernmental Panel on Climate Change (2006) IPCC guidelines for national greenhouse gas inventories. Vol. 1-4.
- Radian Corporation (1996) Methane emissions from the natural gas industry. Volumes 1-15. Prepared for the U.S. Environmental Protection Agency and the Gas Research Institute.
- The Climate Registry (2008) General reporting protocol, version 1.1.
- Minnesota Pollution Control Agency (2012) Greenhouse gas emissions in Minnesota: 1970 – 2008.

⁵ Note: in our Consumption Based Emissions Inventory (CBEI) described in this report, we do not just consider GHG emissions within the geographical boundaries of Minnesota, but rather all the GHG emissions associated with the consumption of goods and services in Minnesota.

Methodology and data sources

The methods used to develop the emissions inventory changes as information and methodologies improve. For example, substantial changes were introduced in 2018. Those changes were reflected in the 2019 biennial report (<https://www.pca.state.mn.us/sites/default/files/Iraq-2sy19.pdf>) and are discussed below.

The methodological changes made after the 2017 report were made to improve estimation of total emissions. To ensure consistency, these changes were applied to all prior inventory years, when possible, including the baseline year of 2005. Revised data used as inputs for estimation were updated when available.

Previously, emissions from the transportation sector were estimated using fuel sales, with the emissions allocated to different modes of transportation using vehicle population, vehicle miles traveled, fuel efficiency, and other fleet statistics. The U.S. Environmental Protection Agency (U.S. EPA) has developed and improved their motor vehicle emissions simulator (MOVES) to estimate GHG emissions as well as criteria air pollutant emissions including carbon monoxide, lead, fine and coarse particles, and nitrogen dioxide. This model was used to estimate Minnesota's transportation GHG emissions beginning in the last report and covers 2005-2018, and uses the same types of fleet statistics as previous reports.

Significant changes were made to estimates of emissions from agriculture and forestry. The methods used to estimate nitrous oxide from agricultural soils were updated to include present scientific understanding and inventory practice based on an inventory framework from the IPCC (2006). New or revised nitrous oxide emission sources include dry deposition, crop residues from cultivated acres and grasslands, mineralization on cropland and grassland, and asymbiotic nitrogen fixation. The emission factor for pastured histosols (peatlands) was also updated.

Emissions of carbon dioxide from cultivation and pasturing of histosols were recalculated using state-level information provided by the U.S. EPA.

Methane is produced when organic matter decomposes without oxygen (anaerobic digestion). The MPCA added sources of methane to the agriculture and forestry sector analysis to account for the production of methane in lakes, wetlands, rivers, streams, and reservoirs.

Forest regrowth removes carbon dioxide from the atmosphere. Given the many unknowns about the future of our forests, we estimate forest carbon residence times as they vary by forest age, type, and carbon pool.⁶ We have adjusted our inventory estimates to account for that understanding.

Uncertainty of estimates

It is difficult to calculate exact amounts of GHG emissions; however, getting a good estimate is still useful to understand magnitude of the problem.

Not all emissions and sinks are included in the statewide total. In some cases, methods have not been developed or data do not exist to support an estimate. The MPCA uses consistent methodologies to allow for meaningful comparisons of emissions over time, including documenting and reporting changes to the methods, and recalculating previous emissions using the new methods.

⁶ This report was edited to correct a statement about forest regrowth in March 2021.

This report summarizes GHG emissions by economic sectors, meaning that emissions estimates are the sum of emissions from activities within the sector. Several methodologies and data sources are used to estimate emissions from each activity within a sector. Some of the methods for generating the estimates are very detailed and are the result of site-specific measurements for both activity and emissions, while others are based on the use of a model with only general data to characterize the source of emissions.

The accuracy of data for different economic sectors can vary:

- Economic sectors that use fossil fuel combustion, such as electricity generation and heating have low uncertainty, especially when aggregated to state totals.
- Emissions from on-road transportation are estimated using the MOVES model, which depends on vehicle population data and vehicle miles traveled, rather than fuel data. Methane generated from municipal solid waste in landfills is also modeled. There is some uncertainty from data inputs and from the underlying equations and assumptions of the model.
- Emissions data for agriculture, forestry and land use has high degree of uncertainty due to the multitude of factors that influence biological processes, as well as difficulty obtaining accurate information such as types of soil, tillage, crops, etc.

Since 2019, MPCA has hired additional data scientists to help improve the accuracy and reproducibility of our emissions data. The data curated using new statistical models and other process improvements will be reflected in the 2023 GHG emissions report.

The MPCA creates the GHG inventory to address all relevant issues in a factual and coherent manner, and to maintain a clear audit trail. We disclose relevant assumptions with appropriate references to the accounting and calculation methodologies and data sources used.

The MPCA manages the GHG inventory to ensure that the quantification of GHG emissions is systematically neither over nor under estimating actual emissions, and uncertainties are reduced as much as practicable.