December 27, 2018

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Chair, Environment and Natural Resources Policy and Legacy Finance Committee
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RE: 2019 Biennial Greenhouse Gas Emissions Reduction Report

Dear Environment and Natural Resources Committee Chairs and Minority Leads:

Please find attached the 2019 Biennial Greenhouse Gas Emissions Reduction Report, written and submitted jointly by the Minnesota Department of Commerce and the Minnesota Pollution Control Agency. This report is being submitted pursuant to Minn. Stat. § 216H.07 subd. 3.
The report discusses the trend of Minnesota's greenhouse gas emissions from 2005 to 2016, as they relate to the Next Generation Energy Act goals.

If you have any questions regarding this report, please feel free to contact Michelle Gransee (Department of Commerce) at 651-539-1855 or Todd Biewen (Pollution Control Agency) at 651-757-2228.

Sincerely,

William B. Grant
Deputy Commissioner of Energy & Telecommunications
Minnesota Department of Commerce

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

WG/GG: fs

Enclosure

cc: Representative Jean Wagenius
Representative-Elect John Persell
Representative Peter Fischer
Stephanie Zawistowski, Office of Governor Mark Dayton
Anna Henderson, Office of Governor Mark Dayton

Climate change

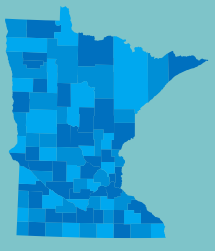
January 2019

Greenhouse gas emissions in Minnesota: 1990-2016

Biennial report to the Legislature tracking the state's contribution to emissions contributing to climate change.

MINNESOTA

Pollution Control Agency
Department of Commerce



lraq-2sy19

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.

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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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Summary: Report to the Legislature

The primary driver behind Minnesota's rapidly changing climate is the emissions of greenhouse gases (GHGs). This report summarizes what we know about the role of GHGs in Minnesota and what the Minnesota Pollution Control Agency (MPCA), Department of Commerce, and other state agencies are doing to track and reduce GHG emissions, comply with relevant state and federal laws, and prepare for the coming impacts of a changing climate.

Key points:

- While Minnesota's overall GHG emissions declined 12% relative to 2005 levels, we missed the Next Generation Energy Act's goal of a 15% emissions reduction by 2015.
- Emissions from electricity used by Minnesotans are down by about 29% since 2005. This means the electricity generation sector has met the Act's 2015 goal, and has nearly reached the 2025 emissions reduction goal. Moreover, Minnesota's utilities have committed to additional coal plant closures that will further reduce GHG emissions from this sector in the future.
- Transportation is now the largest source of GHG emissions in Minnesota. This sector will require ongoing, focused effort to reduce emissions to the levels necessary to meet statutory goals.
- Growth in our forests contributed to the sequestration of carbon and reduced total GHG emissions. If this growth can be sustained over long periods of time, Minnesota's forest resources can help us achieve our emission reduction goals.
- Agricultural nutrient management is the largest source of nitrous oxide (N_2O) emissions, but many best management practices that protect water quality from nutrients and sediment also can help reduce GHG emissions.

Introduction

According to the Minnesota Climatology Office, our state's climate is changing rapidly, and these changes – driven largely by human activities that cause emissions of greenhouse gases – are affecting our health, well-being, ways of life, and natural resources. State agencies are working to protect Minnesotans facing these challenges, and are helping to lead and shape the national conversation about the impacts of climate change and ways we can adapt.

Between 2005 and 2016, total GHG emissions in Minnesota fell by 12%. We did not meet our 2015 reduction goal of 15%.

Tracking GHG emissions and understanding their sources are important ways the MPCA helps Minnesotans navigate our changing climate. Collecting and analyzing data helps identify opportunities and challenges for reducing GHG emissions. The Minnesota Department of Commerce protects the public interest by ensuring that energy resources are reliable, affordable, and increasingly clean. Understanding Minnesota's GHG emissions and emission sources helps Minnesotans mitigate and adapt to a changing climate.

To learn more about climate change in Minnesota and what the MPCA is doing to track GHG emissions, visit our website at https://www.pca.state.mn.us/air/climate-change-minnesota.

Greenhouse gas emissions in Minnesota

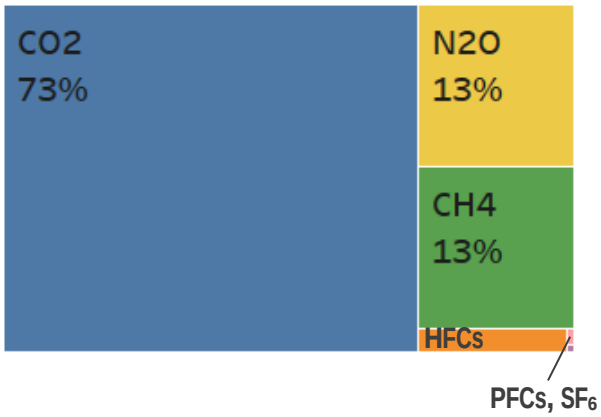
GHGs are gases that warm the atmosphere and surface of the planet. Human activity has been increasing the amount of GHGs in the atmosphere, leading to changes in the earth's climate. The primary GHGs are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulfur hexafluoride (SF_6), and two classes of compounds called hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). Figure 1 shows the relative proportions of GHG emissions in Minnesota in 2016.

CO_2 is the most abundant GHG and has had the largest effect on our climate. Other GHGs are emitted in smaller amounts, but can trap heat more effectively than CO_2, and some stay in our atmosphere for a very long time. "Global warming potential" is a relative measure of how much heat a GHG traps in the atmosphere. Because we need to compare these different emissions and pollutants, we use the effect of CO_2 on our climate as a common reference. In this report, emissions are reported as "CO_2-equivalent" (CO_2-e) tons, meaning emissions are stated in terms that reflect their global warming potential.

GHGs come from a variety of sources:

- Fossil fuel combustion is responsible for most CO_2 emissions in 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 (CH_4) emissions. Methane also is emitted from the anaerobic decomposition of organic material.
- Over 50% percent of nitrous oxide (N_2O) emissions are caused by agricultural nutrient management practices.
- The majority of HFC emissions are from their use in refrigerants, such as in air conditioning, in both vehicles and buildings.

Figure 1. GHG emissions in Minnesota in 2016 (CO_2-equivalents)



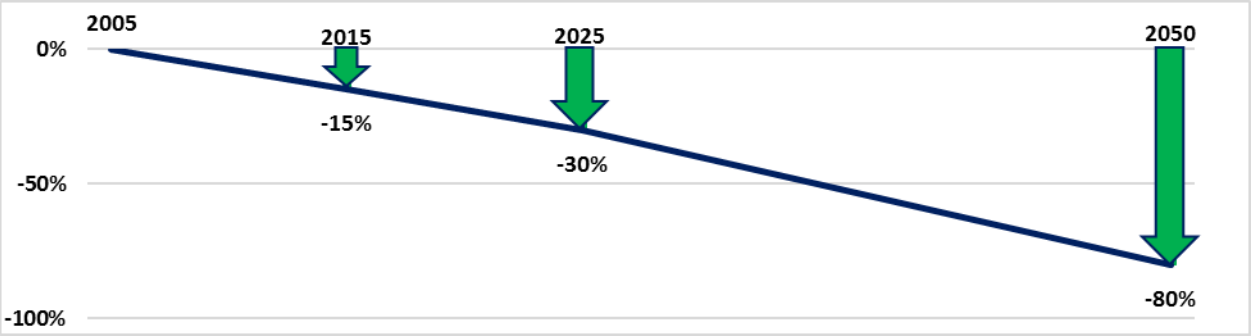
- PFCs and SF_6 only account for a small portion of GHG emissions and are emitted as the result of technical applications, like semiconductor manufacturing and electricity transmission.

In Minnesota, CO_2 emissions account for about 73% of total emissions, while methane and nitrous oxide each account for about 13%.

Tracking Minnesota's emission reduction progress

In 2007, the Legislature passed the Next Generation Energy Act (NGEA), which set interim and long-term goals for the reduction of GHG emissions in the state. Figure 2 shows the goals, establishing a 2050 reduction of 80% below the 2005 baseline[1].

Figure 2. Next Generation Energy Act (2007) greenhouse gas emissions reduction goals. These goals are codified in Minn. Stat. § 216H.02.



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

Missing our first milestone: 2015 emissions

Although mitigation actions have prevented an increase in GHG emissions, Minnesota did not reach the NGEA's 2015 emissions reduction goal of 15% relative to the 2005 baseline. Across all sectors, GHG emissions fell by about 5% from 2005 to 2015; without actions taken within the state, GHG emissions would have risen over that time. This decrease was driven primarily by steep declines in GHG emissions from electricity generation.

From 2005 to 2015, GHG emissions decreased by 5%. Thus, Minnesota did not meet the 2015 interim goal of a 15% reduction.

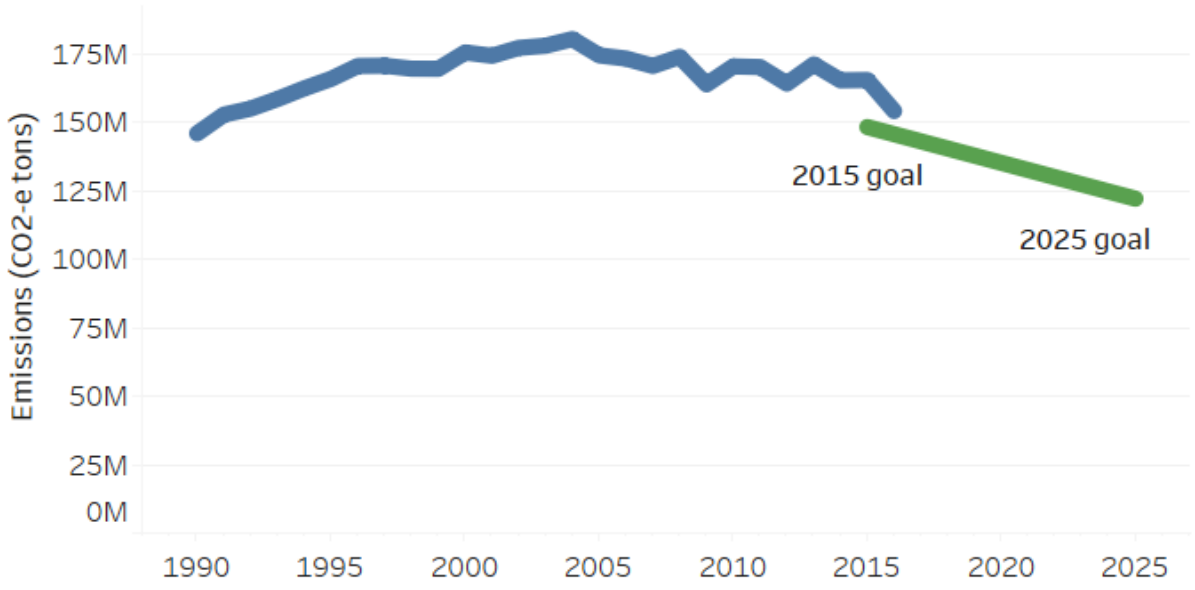
Table 1 shows Minnesota's progress in reducing emissions from 2005 through 2016, while Figure 3 shows how emissions have changed during that time.

Table 1. Actual GHG emissions in Minnesota compared to GHG emissions reduction goals set in the Next Generation Energy Act (2007), 2005-2016.

Year	Actual emissions (million tons CO_2-e)	Actual percent decrease from baseline*	Emissions goal (million tons CO_2-e)	Goal percent decrease from baseline*
2005	174.6	---	---	---
2015	165.6	5	148.4	15
2016	154.2	12	---	---

*Emissions reduction goals in the act are based on actual emissions in Minnesota for the year 2005. Thus, the baseline for reduction is equal to 174.6 million tons CO_2-e.

Figure 3. Minnesota's GHG emissions, 1990-2016, compared to the 2015 and 2025 goals of the Next Generation Energy Act. Although emissions are decreasing, we did not meet the 2015 emissions reduction goal.

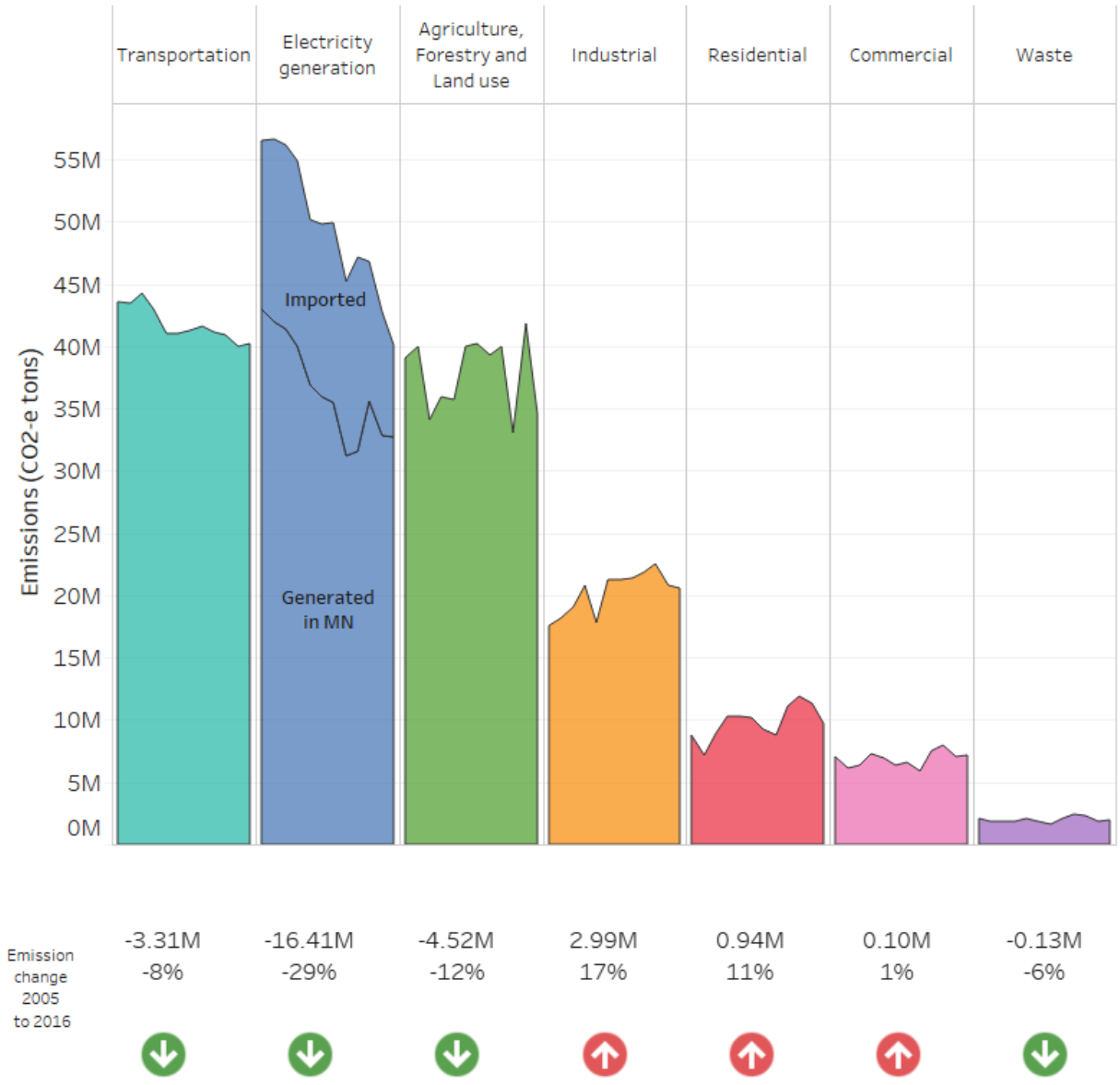


Changing economy, changing emissions

Despite missing the NGEA's 2015 interim goal, Minnesota is making progress in many areas. This section discusses GHG emissions changes across seven economic sectors in Minnesota: transportation, electricity generation, agriculture and forestry, industrial, residential, commercial, and waste.

Figure 4 compares GHG emissions in each of the seven economic sectors from 2005 to 2016.

Figure 4. Minnesota's GHG emissions from economic sectors, 2005-2016. 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 imported electricity (above the line).



Transportation

The trend towards larger vehicles and more miles traveled is preventing more significant emissions reductions in the transportation sector.

This sector will require ongoing, focused effort to reduce emissions to the levels necessary to meet our goals.

Emissions in the transportation sector include on-road vehicles, airplanes and other aviation equipment, trains, leaky vehicle air conditioning units, and natural gas transmission pipelines. More than 70% of emissions from the transportation sector come from light-duty trucks, passenger vehicles, and medium to heavy-duty trucks. GHG emissions from transportation have decreased by 8% since 2005, and account for about one quarter of the GHG emissions in Minnesota. In 2016, emissions from transportation and electricity generation were about the same[2]. Since emissions from electricity that is generated in Minnesota have been reduced over time and are expected to decrease further, transportation is now the largest source of GHG emissions generated within the borders of Minnesota.

Our personal choices have an impact on emissions. On-road vehicles are the largest category of greenhouse gas emissions within the transportation sector. Federal regulations have resulted in newer vehicle models that are generally more fuel-efficient and therefore produce fewer GHG emissions than older, similar vehicles. However, at the same time Minnesotans are choosing to drive larger, less-efficient and more-polluting vehicles instead of smaller, more-efficient cars. Minnesotans are also driving more miles in those larger vehicles. While federal fuel efficiency standards are putting downward pressure on vehicle GHG emissions, the trend towards larger vehicles and more miles traveled is preventing more significant emissions reductions in this sector. The increased emissions from driving larger vehicles more miles offset reductions otherwise achieved by newer, fuel-efficient vehicles.

The state can support greater GHG reductions from transportation while ensuring that Minnesotans have access to varied transportation options. State government is doing its part by using hybrid or fully electric vehicles and supporting community actions to use alternative transportation. Read more in the "Moving forward" section about what we are doing to help meet the NGEA goals.

Electricity generation

In 2016, GHG emissions from electricity generation were about 29% lower than in 2005.

GHG emissions from electricity generation are mostly the result of fuel combustion used to generate electricity consumed by Minnesotans, including electricity generated outside of Minnesota. Other sources include methane from coal storage and hydroelectric reservoirs, CO_2 from flue-gas desulfurization, and SF_6 from electricity transmission and distribution.

Historically, the electricity sector has been the largest source of GHG emissions in Minnesota; in 2016, however, emissions from electricity generation and transportation were about the same[2]. Emissions from the electricity sector have declined 29% since 2005. The decrease is largely due to reductions in the amount of coal burned to generate electricity and increased use of renewable energy.

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

Our total GHG emissions from electricity generation include emissions from electricity generated outside of our state borders, but which we use here. We can also look at just the GHG emissions from electricity generated at facilities within the state. Emissions from in-state generation fell 24% from 2005 to 2016. The amount of electricity that we generate in Minnesota increased at a faster rate than the total amount of electricity Minnesotans consume, which reduces the amount we estimate as imported.

In reality, electricity freely flows across boundaries; we created an accounting framework, based on available data, which takes responsibility for emissions from in-state facilities and in-state consumption of electricity generated elsewhere. In Minnesota and surrounding states, however, coal is being replaced by renewable wind and solar energy, along with natural gas. Recent decisions in utilities' integrated resource plans will reduce GHG emissions from this sector further.

Agriculture and forestry

Emissions sources in the agriculture and land use sector include livestock, animal feedlots, manure, fertilizer, crop cultivation practices, anaerobic decomposition of organic material, and related fuel combustion of off-road implements like tractors and combines. Carbon also is sequestered in forest regrowth, which is captured in the emissions from this sector.

Growing Minnesota forests are contributing to significant carbon sequestration. If we can sustain stand growth, our forest resources can help us reach our emissions reduction goals.

Compared to the 2005 baseline, emissions from the agriculture and forestry sector have decreased about 12%, but emissions have been highly variable between 2005 and 2016. The largest source of N_2O emissions is nutrient management, which includes fertilizer use, nitrogen fixation, mineralization, and runoff. N_2O emissions from crop agriculture increased by about 12% from 2005 to 2016.

We can achieve reductions from this sector by improving best management practices, as many BMPs for nutrient use and sedimentation also act to decrease GHG emissions. Some of the more promising practices for reducing GHGs from agriculture include improved efficiency of nitrogen use (through optimized fertilizer application rates, timing, and placement), conservation cover, riparian buffers and related vegetative filter strips and field borders, and cover crops.

Animal agriculture is the largest source of methane emissions, specifically from manure management and cattle digestion. Methane emissions from animal agriculture increased by about 8% from 2005 to 2016. Our lakes, rivers, and reservoirs are another large source of methane emissions, from the breakdown of biological materials in sediments.

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 2016 increased, which then offset GHG emissions from other agricultural activities.

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, and the manufacture of steel, glass, insulating foam, and semiconductors.

Since 2005, emissions from this sector have increased by about 3 million tons CO_2-e; in 2016, emissions were about 17% above the baseline.

There has been an overall increase in energy used in the industrial sector since 2005, but industrial energy use has decreased from its peak in 2014. Within the total energy trends, coal use has continued to decline steadily. Natural gas use has increased since 2005, but has remained relatively stable since 2010, peaking in 2014.

CO_2-e emissions data for individual sources with MPCA air permits are available on our website, at https://www.pca.state.mn.us/air/permitted-facility-air-emissions-data.

Residential

Emissions sources in this sector include fuel combustion for heating and in-home appliances, like water heaters or clothes dryers, and from other sources, including fertilizer use, product use, food additives, and refrigerant leakage from air conditioners and refrigerators. Emissions from electricity use are all included in the electricity generation sector rather than divided between consumers in each sector.

Since 2005, emissions from the residential sector have increased by about 0.9 million tons CO_2-e; in 2016, emissions were about 11% above the 2005 baseline.

Carbon is also stored in wood construction materials for periods long enough that carbon is effectively removed from the atmosphere, reducing total emissions.

Commercial

Emissions sources in this sector include fuel combustion, solvent use, and medical N_2O emissions. Institutional emissions are counted in this sector, as well. Commercial-sector emissions have shown an increase of just 1% above the 2005 baseline in Minnesota.

Waste

Emissions sources in the waste sector include energy use in waste processing, incinerator fuels and waste incineration, and methane from landfill gas and wastewater treatment. Carbon is also stored, or sequestered from the atmosphere, as wood waste in demolition and construction landfills, which offsets emissions.

Compared to the 2005 baseline, GHG emissions from waste have decreased by about 6%. This is a change from 2014, when waste emissions were greater than they were in 2005.

The MPCA has been working to address methane emissions as the administrator of the state's closed landfill program.

Greenhouse gas emission intensity

Employment in Minnesota's clean energy sector grew faster than total state employment between 2000 and 2014.

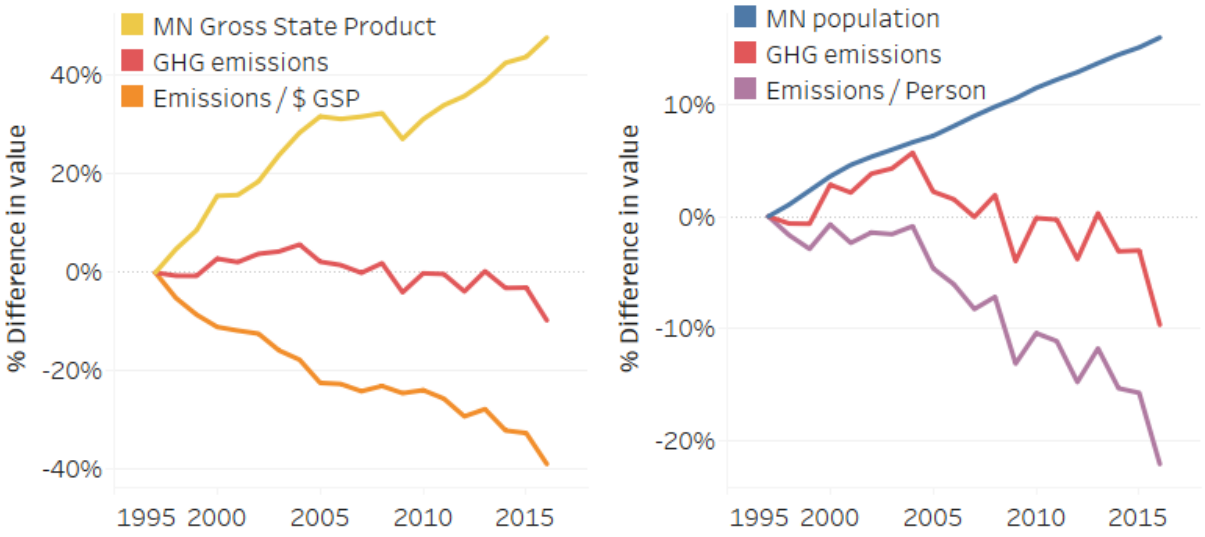
In 2017, there were about 59,000 clean energy jobs – over 2% of our entire 2017 workforce.

As Minnesota's economy and population grow, our GHG emissions have declined, which shows that we can support healthy communities and ecosystems, as well as a strong economy. These trends indicate we can continue to curb GHG emissions, while still growing and thriving.

Measuring the amount of GHG emissions compared to other economic trends 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 1997, while GHG emissions have remained relatively flat. What this means is that our state economy can grow without increasing GHG emissions. In fact, Minnesota's experience shows that strong economic growth occurs at the same time that we are reducing GHG emissions. Figure 5a shows this relationship.

Minnesota's experience shows that we can grow our population while reducing our per capita GHG emissions. While the population in Minnesota is increasing, and is projected to continue increasing, there is a net decrease in how much each individual on average is emitting. Figure 5b shows this relationship.

Figure 5a (left). Minnesota's GHG emissions per dollar gross state product (GSP), 1997-2016.
Figure 5b (right). Minnesota's GHG emissions, per capita, 1997-2016.



Moving forward: What else are we doing?

Here are some ways that the MPCA and the Minnesota Department of Commerce are working with other state agencies, Minnesota businesses, and other state and national partners to further reduce GHG emissions in Minnesota.

Reducing state government emissions

The Office of Enterprise Sustainability is providing leadership to all state agencies in efforts to curb GHG emissions. So far, these efforts, including expanding the use of EVs and installation of solar panels, have reduced state government emissions by about 17% from 2005 to 2017.

These efforts were initiated by Governor Mark Dayton's Executive Order 17-12, which directs state agencies to reduce waste, conserve energy, and save money. One of the objectives of the executive order was to reduce GHG emissions created during day-to-day enterprise operations. State agencies came together to identify reduction strategies, including reducing fuel consumption in state vehicles, reducing energy consumption in buildings, and implementing existing renewable energy policies.

Due to these efforts, state government is over halfway to the order's goal of 30% reduction by 2025, with half of the decrease coming from electricity savings, reduced square footage of workspaces, and on-site renewable energy generation across state agency offices. Future initiatives include transitioning many light-duty fleet vehicles to electric, exploring the use of more biofuels in medium- and heavy-duty vehicles, implementing a building retro-commissioning program to conserve energy, and installing solar panels at state office and workspace locations.

For more information about how state government has reduced GHGs, check out the Office of Enterprise Sustainability's 2017 report, at https://mn.gov/admin/assets/2018%20annual%20report_web_tcm36-355173.pdf.

Participating in national and international climate change initiatives

Minnesota is a member of various national and international coalitions working to reduce GHG emissions and move forward with actions to mitigate climate change. In 2015, Minnesota joined the Under2 Coalition, an international group comprising over 200 state, regional, and national governments committed to keeping global temperature increases to under 2 degrees Celsius. The coalition aims to find pathways for "deep decarbonization," innovative policy solutions, and systems to improve emissions reporting and policy development. More information can be found at https://www.under2coalition.org/.

In 2017, Minnesota also joined the U.S. Climate Alliance, a bipartisan group of state governors committed to reducing GHG emissions consistent with the goals of the United Nations Paris Agreement. As a member of the alliance, Minnesota agrees to implement policies that advance the goals of the Paris Agreement, track and report progress to the global community, and accelerate new and existing policies to reduce carbon pollution. More information can be found at https://www.usclimatealliance.org/.

Most recently, in September 2018, Minnesota joined the Powering Past Coal Alliance, an international group of state, regional, and national governments, businesses, and organizations dedicated to advancing the transition of power generation away from coal. Members of this alliance believe that moving away from coal power generation is necessary to promote clean air, healthy communities, sustainable economic growth, and a safe climate. As a part of this alliance, Minnesota is committed to work with our utility partners to move towards a future of renewable energy generation and to reduce our reliance on coal. More information can be found at https://poweringpastcoal.org/.

Greening up our energy generation

Minnesota has made great progress toward a clean energy future by substantially reducing GHG emissions from electricity generation. Local utilities continue to close coal plants and replace that power generation with a mix of renewables backed by natural gas. Minnesota's work on clean energy shows we can reduce GHG emissions cost-effectively while our economy continues to grow.

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 worked in tandem with market forces that make many renewable resources more cost-effective than coal facilities. Efficiency projects are often the most cost-effective way to reduce GHG emissions from electricity generation, so they were the first area where Minnesota focused reduction efforts, requiring utilities to invest in energy efficiency for homes and businesses. Utilities have taken advantage of market developments as well: technology improvements and federal tax policies that have lowered the cost of wind and solar energy development, the continued low price of natural gas, and electricity consumers' growing preference for "green" energy.

Over the past two decades, Minnesota adopted several requirements for electricity generation and renewable energy:

- In 2001, the Legislature allowed utilities to charge customers for the cost of air pollution-reduction projects. This law has encouraged utilities to replace coal generation with gas and wind.
- In 2007, the Legislature adopted the state Renewable Energy Standard (RES) that created renewable energy requirements for all utilities operating in Minnesota. By 2025, the RES requires that a weighted 27% of all retail electricity sales in Minnesota come from renewable energy sources. Minnesota's utilities are on track to meet this requirement.
- Also in 2007, the state implemented electric utility requirements to reduce 1.5% of retail sales through programs that target the users of electricity, building on previous successful efficiency programs.
- In 2013, the Legislature adopted a solar energy standard for the state's investor-owned utilities that requires that, by the end of 2020, at least 1.5% of total retail sales are generated by solar energy.

Additionally, several electricity generating facilities, especially those powered by coal, have either recently been retired or are planned to be retired soon. The planned retirements are listed in Table 2.

Table 2. Planned in-state electricity generating unit retirements for Minnesota utilities.

Facility	Fuel type	Size	Retirement date
Minnesota Power			
Boswell Energy Center 1	Coal	67 MW	2018
Boswell Energy Center 2	Coal	67 MW	2018
Taconite Harbor Energy Center unit 2	Coal	76 MW	2020
Taconite Harbor Energy Center unit 3	Coal	83 MW	2020
Silver Bay Power: 2 units	Coal	130 MW	2021
Otter Tail Power Company			
Hoot Lake Combustion Turbine units	Coal	141 MW	2020
Great River Energy			
Stanton Station (North Dakota)	Coal	187 MW	2018
Xcel Energy			
Benson Power Biomass Plant	Biomass	55 MW	2018
Sherburne County 1	Coal	680 MW	2026
Sherburne County 2	Coal	682 MW	2023

Paving the way for cleaner transportation

Minnesota state agencies, local governments, non-profits, and electric utilities are working to accelerate electric vehicle (EV) adoption in Minnesota by educating Minnesotans about the benefits of EVs and leading and supporting initiatives to build out EV charging infrastructure across the state. The state's ongoing transition away from coal to renewable energy is amplifying the benefits of EVs, which can take advantage of GHG emission reductions in the power sector. Special electricity rates for EV owners can encourage Minnesotans to charge their EVs at night, which provides benefits to the power grid.

Minnesota is receiving $47 million under the national Volkswagen settlement, and is targeting 15% (the maximum allowed by the settlement) of our Phase I funds to begin building a statewide network of EV charging stations. This will help expand the reach of EVs and reduce barriers to their adoption. More information about how Minnesota is using VW settlement funds can be found at www.pca.state.mn.us/vw.

In addition to promoting electrification, the MPCA serves as an advisor and technical resource for a wide range of other transportation planning and funding efforts across the state. Transportation planning can

have a big impact on vehicle emissions by promoting investment in infrastructure that supports alternative modes of transportation, like public transit, walking, and biking. We work with partners to encourage land-use planning that provides opportunities for people to live within walking or biking distance of the places they need to get to every day, and to promote the use of public transit.

Developing policies that encourage us to adapt to a changing climate

Many Minnesota state agency programs and policies relating to climate change focus on reducing GHG emissions. Adapting to a changing climate, on the other hand, involves developing and implementing strategies, initiatives, and measures to help us prepare for and address the impacts of climate change.

In its 2017 report, "Adapting to Climate Change in Minnesota," the Interagency Climate Adaptation Team recommended six priority action steps where state government could be of most help:

1. Build greater resilience to extreme precipitation.
2. Identify opportunities to strengthen the health and resilience of vulnerable populations to climate effects through cooperation with local governments.
3. Increase focus on preserving natural and restored ecosystems and habitat to increase resilience of wildlife and native plants.
4. Strengthen agricultural water-management efforts to increase resilience to climate change impacts.
5. Increase focus on managing climate impacts in cities, towns, and other population centers.
6. Strengthen our climate information infrastructure to support adaptation practices.

The MPCA is implementing several of the above recommendations throughout our work. In 2018, we adopted a new cross-agency strategic goal focusing on climate adaptation efforts, and we are creating an information dashboard to display our climate adaptation data. We also are working with community partners to incorporate resilience into planning and infrastructure, identify and reduce risks for climate-vulnerable populations, and implement adaptation best practices. To learn more about the MPCA's climate adaptation efforts, visit https://www.pca.state.mn.us/air/adapting-changing-climate.

The Minnesota Department of Health is working with the MCPA and other state agencies to deal with the effects of climate change on human health. The goal of the Minnesota Climate and Health Program is to help us understand the impacts of climate change, and to educate local public health resources and the public about potential health risks. More information on MDH's Minnesota Climate and Health Program can be found at http://www.health.state.mn.us/divs/climatechange/.

The takeaway

Minnesota has made important progress in reducing GHG emissions, but there is more work to be done to achieve the goals of the Next Generation Energy Act. Significant GHG reductions from the electricity generation sector have driven overall emission trends downward since 2005, aided by smaller improvements in some sectors. These changes show that clean energy laws and programs can and do reduce GHG emissions, but we need to accelerate the pace of progress.

Emissions from Minnesota's electricity generation sector will continue to decrease, as renewable sources account for greater amounts of the energy produced and used here. In order to achieve our GHG emissions reduction goals, however, we will need to further reduce emissions from what is now our largest source of in-state emissions, transportation. Supporting and promoting the use of EVs, supporting the use of cleaner transportation fuels (such as biofuels), encouraging the use of public and multimodal transportation, and mindful transportation planning are crucial elements in decreasing GHGs from transportation.

Minnesota has been and will remain a leader in GHG emission trends, but without continued support and additional effort, we are not likely to achieve the goals of the Next Generation Energy Act.

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 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.

GHG inventory protocols require that evaluation of state-level GHG emissions take into account photosynthetically-removed CO_2 stored in biomass in forests, landfills, and structures. Carbon storage and emissions from forest soils 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 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 2016, though presented here in an abbreviated timeline. With a few exceptions, the methods used to develop these estimates are derived from the following sources:

- US Environmental Protection Agency (2018) Inventory of US greenhouse gas emissions and sinks: 1990-2016.
- 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 US Environmental Protection Agency and the Gas Research Institute.
- The Climate Registry (2008) General reporting protocol, version 1.1.
- Minnesota Pollution Control Agency (January 2012) Greenhouse gas emissions in Minnesota: 1970 – 2008.

Updates to methodology and data sources

Except for changes within the agriculture and forestry sector, the methods used to develop the emission estimates are largely unchanged from previous reports. The methodological changes made since the last report were made to improve estimation of total emissions. To assure 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.

Significant changes were made to estimates of emissions from agriculture and forestry. The methods used to estimate N_2O 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 N_2O 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 was also updated.

Emissions of CO_2 from cultivation and pasturing of histosols were recalculated using state-level information provided by the EPA.

Sources of methane were added to the agriculture and forestry sector to account for the production of methane in lakes, rivers, streams, and reservoirs.

Forest regrowth was added as a source of carbon sequestration. 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 adjusted our inventory estimates to account for that understanding.

Prior to the 2017 Biennial Greenhouse Gas Emissions report, emissions from the transportation sector had been 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 EPA has developed and improved their motor vehicle emissions simulator (MOVES) to estimate greenhouse gas emissions as well as criteria air pollutants. This model was used to estimate Minnesota's transportation GHG emissions beginning in the last report and covers 2005-2016. The MOVES model uses the same types of fleet statistics, but estimates energy and fuel consumption as model outputs.

Uncertainty of estimates

The MPCA developed its GHG Emission Inventory system with the following in mind: the long record of emissions covering periods of years to decades; a consistent time series of estimates; best international and US practices; high level of data disaggregation; and timeliness. Reflecting these principles, this GHG inventory is:

Complete: This inventory accounts for and reports on Minnesota GHG emission sources and activities within the chosen inventory boundary, as described in the MPCA's GHG Inventory Technical Support Document. 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.

Consistent: The MPCA uses consistent methodologies to allow for meaningful comparisons of emissions over time. Changes to the methods are documented and reported.

Transparent: The MPCA administers the production of the GHG inventory to address all relevant issues in a factual and coherent manner, and to maintain a clear audit trail. Relevant assumptions are disclosed with appropriate references to the accounting and calculation methodologies and data sources used.

Accurate: The MPCA administers the GHG inventory to ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, and as far as the MPCA can judge, uncertainties are reduced as far as practicable.

With this report, the MPCA is providing a qualitative discussion of the uncertainty of emission estimates. Uncertainties around the precision and accuracy of estimates arise and the acknowledgement of uncertainty is not intended to invalidate the estimates. The uncertainties in the reported greenhouse gas estimates are reduced as far as is practical. In future inventories, the MPCA may provide quantitative uncertainty analysis.

This report summarizes GHG emissions by economic sectors, meaning that emissions estimates are the sum of emissions from activities within the sector. Many 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 some are based entirely on the use of a model with only general data to characterize the source of emissions.

As a result, it is not accurate to assign a single quality rating to the entire economic sector estimate at this time. Within each sector, the confidence in data quality can vary. Generally, the more regulated activities have high-quality activity and emission data.

On the whole, fossil fuel use and emissions are very well understood, especially when aggregated to state totals. For example, the quantity of natural gas used in the state leaves little uncertainty, but there is some uncertainty in distributing its use among sectors. Fossil fuel combustion from stationary sources, such as power plants, creates about 50% of our GHG emissions. These emissions are estimated using highly reliable methods, like continuous emissions monitors in place for other regulatory reporting requirements, by mass balance calculations, or by factor calculation from fuel consumption.

All transportation emissions account for about 25% of our GHG emissions. 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. There is some uncertainty from data inputs and from the underlying equations and assumptions of the model.

The MPCA has undertaken improvement projects which reduce uncertainties to the extent that is practical and where data allows. Comparisons can be made across time because of the consistent revision of the inventory. Conclusions about reaching Minnesota's GHG reduction goals can be drawn from the inventory when its limits are understood.