Oct 28, 2019
House Environmental Resources & Energy Committee
Public hearing - Pennsylvania CO2 and Climate
Testimony of Irina Marinov, University of Pennsylvania.

I am Irina Marinov, an associate professor and climate scientist in the Earth and Environmental Science Dept. at University of Pennsylvania. I am here today as a scientist, as a teacher of college students, as a resident of West Philadelphia and as a mother of two young boys to tell you that I am concerned. I am concerned about the future of our planet, and the future of our children.

My specialty is in running climate models and analyzing climate data from the past and projections of climate for the future. I am here today to not only present my individual science but to share with you the opinion of the 98% majority of the climate scientists globally and in the US. While uncertainties in our science remain and our job as scientists is far from over, there are some very clear facts. I am here to summarize findings from the following reports:

- *IPCC Report, 2013.*
- *IPCC Special Report on the 1.5C change, 2018*
- *Fourth National Climate Assessment, 2018*

These reports represent the peer-reviewed summaries of the scientific literature, and by construction they represent a conservative estimate of the state of the science. These reports tell us that climate change is real and is happening today, and we can ascribe with high certainty many of the changes we see around us to the addition of greenhouse gases such as CO_2 to the atmosphere, mostly through energy production and transportation.

1. <u>The Science for our region is summarized in the NE Chapter of the National Climate Report (2018) and in the *Pennsylvania Climate Impacts Assessment Update* (2015). In summary we can report that:</u>

- Weather is changing in PA, starting with an increase in precipitation, more very wet months, more frequent heavy rains, increased flooding. The current year is the wettest year on record in Philadelphia.
- Pennsylvania has undergone a long-term warming of more than 1 °C (1.8°F) over the past 110 years. Under the "business as usual" (so-called RCP8.5) emission scenario, it is projected that by 2050, PA will be about 3°C (5.4°F) warmer than it was at the end of the 20th century. The corresponding annual precipitation increase is expected to be 8%, with a winter increase of 14%. The likelihood for drought is expected to decrease while months with above-normal precipitation are expected to increase.
- The Northeast generally is projected to experience some of the largest adverse health impacts from climate change, including damages from lost labor hours and deaths associated with increases in extreme temperatures and worsened air quality. Projected damages by year 2100 are summarized in Figure 1.
- All the major economic sectors of Pennsylvania including energy, water, and transportation infrastructure will be affected by changes in snow storms, drought, heat waves, and flooding. Examples of climate impacts include increased energy demand during summertime and severe, negative impact on winter recreation. PA's downhill ski and snowboard resorts are not expected to remain economically viable past mid-century.
- Warmer ocean temperatures, sea level rise, and ocean acidification threaten coastal and ecosystem services in the Northeast. Climate change will also increase the stress on Pennsylvania's tidal wetlands and will worsen the currently substandard water quality in the tidal freshwater region of the Delaware Estuary. One reason is that increased water temperatures with climate change decrease the solubility of oxygen in water and will increase respiration rates, both of which will result in declines in dissolved oxygen concentration. The second reason that climate change threatens tidal freshwater fauna is through salt intrusion associated with sea-level rise and summertime streamflow declines.

2. The global Science is also clear, as shown by the IPCC 2013 and IPCC 2018 reports. In summary:

- Human activities are estimated to have caused approximately 1.0 C of global warming above pre-industrial levels, with a likely range of 0.8C to 1.2C. Global warming is likely to reach 1.5 between 2030 and 2052 if it continues to increase at the current rate (IPCC 2018). The four warmest years since records began in the mid to late 1800s have all occurred since 2015. Global sea level in 2018 was the highest in the modern record and continues to rise (State of the Climate 2018).
- In 2018 alone there were 14 weather and climate events during the year that caused over $1 billion US dollars in damages, the fourth highest in terms of cost since records began in 1980. (ref: State of the Climate, 2018).
- We expect climate change will cause extreme weather events – like heat waves, heavy rainfall, floods and droughts – to become more frequent and more severe. Under high levels of warming, very intense hurricanes are expected to occur more frequently, although the overall number of hurricanes is expected to fall.
- We are currently moving dangerously close to a path where the increase in temp by 2100 will be at 3° to 6 °C relative to preindustrial times (Figure 2). This is worrisome, as the IPCC 2018 Report points to even an increase in temperature of 2° degrees as very dangerous.

3. Does PA matter in the global context of CO2 emissions and global climate change?

- PA is the 6th economy in the US by GDP. PA is the 2nd energy producer in the US, including the 2nd producer of natural gas and 3rd producer of coal in the US. PA emissions in 2016 were 218.6 million metric tons of CO2, making it the 4th CO2 emitter in the US. (all numbers for 2016 from the US Energy Information Administration https://www.eia.gov/state/).
- The EPA "Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2017" lists the total US emissions in 2017 as 6,457 Million Metric Tons of CO_2 equivalent of which 5,271 are due to CO2 emissions and 656.3 are due to methane emissions.
- More relevant to the energy sector, US energy-related emissions in 2016 are reported as 5,189 million metric tons of CO2 (MMmt). Of these, PA is responsible for 218 million metric tons of CO2 emissions which represent 4.2% of the US quota (www.eia.gov/state/)

Therefore, because of its sheer size as an energy producer and as Greenhouse Gas producer, PA plays a large role in the global emissions of CO2 and can similarly play a large role in reducing global emissions.

- One good news we have heard is that the US carbon dioxide emissions have flattened over the past few years, as coal production has been replaced by abundant, cheap natural gas production in PA and elsewhere. Natural gas is better than coal, in that processing of natural gas combustion produces less CO2: for example PA coal plants emit on average more than one ton of CO2 per MW-hr generated, while natural gas emits half as much. But let us be clear here. *Fracking of natural gas also produces climate change.* Taking natural gas out of the ground and combusting it causes climate change. With this in mind, how much do we want to lock ourselves into the future by building more plants that will be around for the next 40-50 years?
- As we proceed forward, we need to keep in mind that the global warming potential for methane (on the 100-year time horizon) is about 25 times that of CO2, i.e. methane warms much more our planet per molecule emitted than CO2. One concerning emerging issue is the leakage of methane (CH4) associated with fracking. There is discussion in the current literature as to what the precise methane emission from fracking are, whether the EPA estimates from recent years are under-estimates, and whether the recent spike in US methane emissions is from fracking. Therefore, it is essential that any future emission goals include very clear plans for methane, as well as other tertiary greenhouse-gases.

4. What can the world do to fix the climate change problem?

- Climate-related risks for natural and human systems depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability and on the choices and implementation of adaptation and mitigation options (IPCC 2018). Our cumulative emissions of CO2 and future CO2 emissions determine our probability of limiting warming to a given level. In other words, any action that we take today will have big implications for tomorrow.
- The opinion of climate science community and of all relevant US agencies (NOAA, NASA, EPA) as formulated in the IPCC Reports and in the National Climate Assessment of 2018, *is that the only way forward towards a healthier environment is to deeply decarbonize our economy*. In order to achieve the goals of the Paris agreement, the cuts in the greenhouse gases need to be profound.

- The goal of the Paris Agreement is to limit warming to well below 2°C (1°C warmer than today) and to attempt to restrict warming to 1.5°C (0.5°C warmer than today). The world is are currently not on track to limit warming to 1.5°C; in fact, current emission reduction pledges made by nations in the Paris Agreement would lead to warming of 3-4°C by the end of this century (IPCC 2018).

- To keep warming within 1.5°C, we need to achieve cuts of anthropogenic CO_2 emissions by 45% from 2010 levels by 2030, reaching net zero around 2050. To limit warming to below 2°C, global CO_2 emissions must decline by 25% by 2030 and reach net zero around 2070. In both cases, a substantial global effort to reduce emissions is needed in the next few decades and without delay. We need collective action that is rapid, far-reaching and unprecedented in terms of scale, which include far-reaching transitions and deep emission reductions in energy, land, urban and infrastructure (including transport and buildings) and industrial systems. A desired broad-strokes economic plan is outlined in the IPCC 2018 Report.
- If we delay action now, more rapid emissions reduction will be needed in the future to limit warming to the same level, and these emissions reductions will be more costly.

- ***Pennsylvania seems ideally placed to become a leader in the US in the reduction of greenhouse gas emissions,*** as shown in the Tables attached below. Indeed, data from https://www.eia.gov/state/ ("Energy-related CO2 emissions by State, 2005-2016", Feb 2019, US Dept of Energy, see Tables on pages 9-10) suggests a vast drop in energy-related carbon emissions in Pennsylvania over the 2005-2016 period. PA was responsible in 2016 for 218.6 million metric tons of CO_2 emissions, which represented 4.2% of the US quota. PA energy-related emissions fell from 2005-2016 by 22.8% (or 64.7 million metric tons). This is better than the US average drop of 13.4% (or 802 million metric tons). **In other words, PA contributed more than twice its emission share to the drop in US CO2 emissions from 2005 to 2016.**

- In parallel, per capita energy-related CO2 emissions in PA fell from 22.4 to 17 metric tons CO2/person from 2005 to 2016. This is a 24% drop. Overall in the US, the per capita energy-related CO2 emissions dropped from 19.9 to 16 metric tons CO2/person, a 20% drop over the same period. To keep in mind, the average per capita CO2 emissions globally are 4.8 tCO2.
- Gov. Wolf proposed goals (executive order 2019-01) are to achieve a 26% reduction of net GHG emissions statewide by 2025 from 2005 levels, and an 80% reduction of net GHG emissions by 2050 from 2005 levels. In light of the current big advances and CO2 emission reductions in PA, **PA seems ideally positioned to become a leader in the US in decarbonization**. Indeed, these numbers suggest that PA can achieve **more** than the targets proposed by Governor Wolf. PA should aspire for a zero net GHG emissions by 2050, in line with the IPCC 2018 report suggestions.
- I hope to see PA join the RGGI cap-and-trade program and then – within this framework - immediately work towards pushing for ***much more stringent limits on carbon and methane emissions in the Northeast.*** I want to see PA's aggressive and fast development of renewables and nuclear energy, *with aggressive and clearly specified goals and quotas for renewables and nuclear energy*. I want to see a detailed plan for the

use of Carbon Dioxide removal mechanisms including afforestation and reforestation, land restoration and soil carbon sequestration, direct air carbon capture and storage. I hope to see a discussion about energy crops and increased forest surfaces, intensification of land-use practices and ecosystem restoration, in line with the suggestions of the IPCC and National Climate reports.

You have jobs that are much harder than mine that I do not envy. You need to lead PA in taking ***rapid, far-reaching and unprecedented action*** to make PA both an economic and environmental leader in the US, deliver on the recommendations of the US Climate Change Report and various IPCC reports and ensure a healthy planet for our children. How to achieve such a large transition while balancing social well-being, economic prosperity and environmental protection for PA is an extremely complex juggling act. It is my hope that us, the concerned PA citizens and parents, the scientists and academics can support you in a transformation transition for our planet.

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EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2017
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

US Energy Information Administration, Energy-Related Carbon Dioxide Emissions by State, 2005-2016, https://www.eia.gov/environment/emissions/state/analysis/

FIGURES:

Figure 1. Annual damages for the ten sectors with the greatest projected costs in the Northeast in year 2090 under the business-as-usual scenario (so-called RCP8.5). Numbers are shown in $billions. Second set of data shows avoided costs if climate mitigation is performed.
Reference: Fig 30.2, Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. 2017, *U.S. Environmental Protection Agency*, Washington, D.C. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=335095

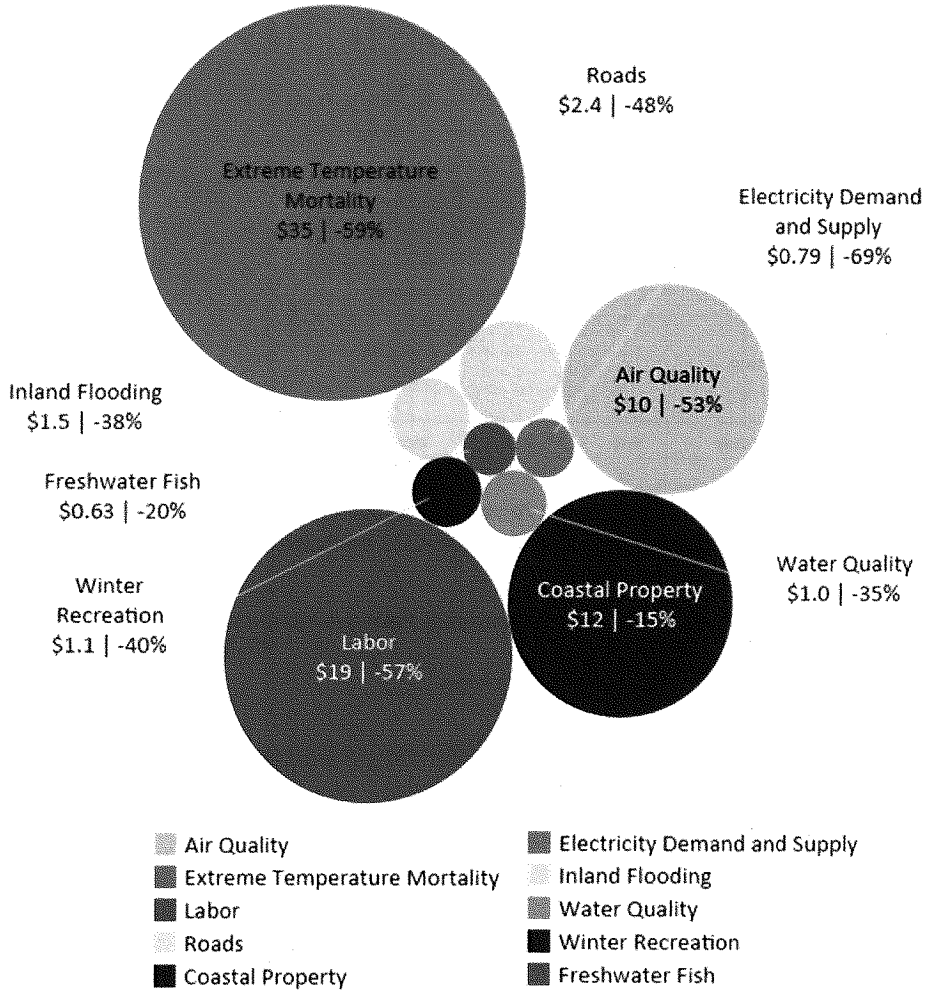


Figure 2. Figure adapted from the IPCC 2018 Special Report on Global Warming of 1.5C. Figure shows observed temperature changes relative to 1850-1900 and projected temperature changes. Human-induced warming reached ~ 1C relative to preindustrial temperature in 2017. At the present rate, we will reach 1.5 C by late 2030. To avoid this, we need deep transformations of our economic systems. Possible scenarios that stabilize our temperature at 1.5C are shown in green.

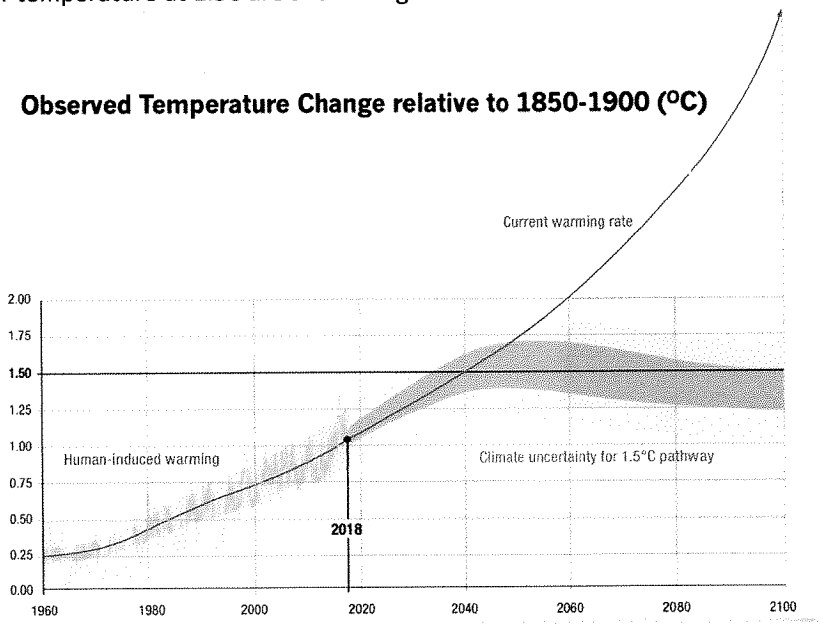
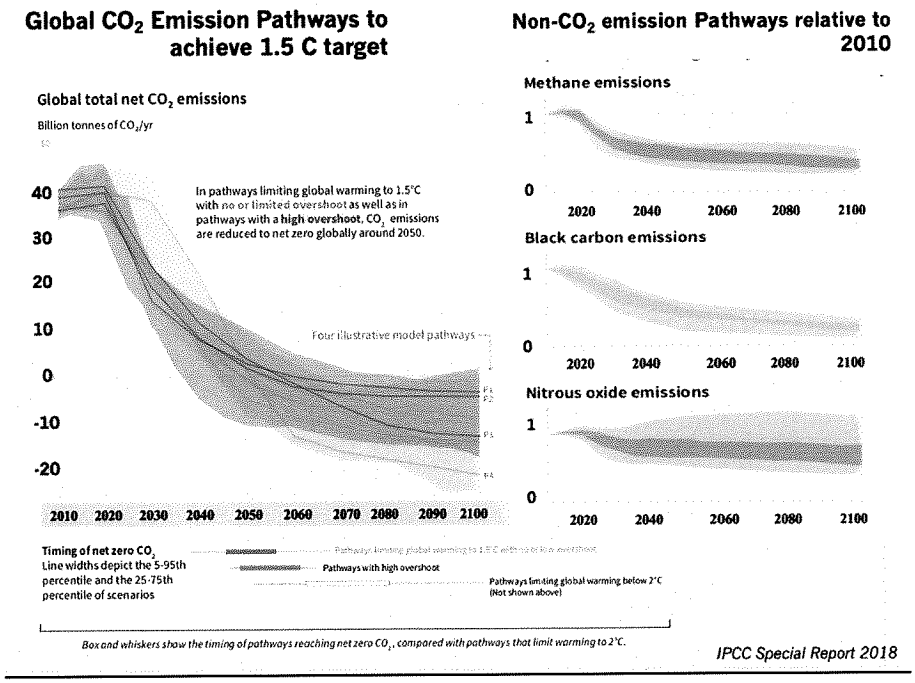


Figure 3. Figure adapted from the IPCC 2018 Special report on Global Warming of 1.5C. Figure shows global CO2 emission pathways to achieve 1.5C target, as well as non-CO2 emission pathways relative to 2010.



Tables 2 and Table 6 from the Energy-related Carbon Dioxide Emissions by State, 2005-2016, released in February 2019. https://www.eia.gov/environment/emissions/state/analysis/

February 2019

Table 2. State energy-related carbon dioxide emissions by year, adjusted (2005–2016)

million metric tons of carbon dioxide

State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Change (2005–2016) Percent	Change (2005–2016) Absolute
Alabama	145.7	148.0	149.6	141.8	121.9	134.6	131.6	125.1	122.5	124.8	121.7	115.7	-20.6%	-30.0
Alaska	49.0	46.6	44.9	40.3	38.6	39.5	39.3	38.8	36.7	35.8	36.7	35.1	-28.4%	-13.9
Arizona	98.3	101.5	103.4	103.8	94.8	96.6	94.6	92.8	96.5	94.4	92.1	87.5	-11.0%	-10.8
Arkansas	61.1	62.9	64.2	65.1	62.4	66.7	68.1	67.0	69.3	69.9	60.0	62.8	2.7%	1.7
California	390.1	398.3	403.1	387.4	373.8	367.8	353.2	358.6	360.7	357.5	365.4	363.3	-6.9%	-26.8
Colorado	96.8	97.7	100.3	98.4	94.2	96.6	92.8	91.9	92.4	92.9	91.6	89.5	-7.5%	-7.3
Connecticut	44.8	41.7	40.8	38.3	36.5	36.8	35.3	34.7	35.4	35.6	37.0	34.5	-23.0%	-10.3
Delaware	17.1	16.0	16.8	15.9	12.2	11.4	12.4	13.6	13.3	12.9	13.0	13.4	-21.5%	-3.7
District of Columbia	4.0	3.2	3.4	3.1	3.2	3.3	3.1	2.7	2.9	3.1	3.0	2.8	-30.2%	-1.2
Florida	265.0	263.2	260.6	242.3	227.7	245.7	232.2	226.3	225.0	230.7	235.2	231.3	-12.7%	-33.7
Georgia	187.4	184.6	187.1	174.5	164.6	174.0	158.4	138.3	136.4	141.4	138.8	137.0	-26.9%	-50.4
Hawaii	23.3	23.5	24.3	19.6	19.1	19.3	19.7	19.2	18.7	18.6	18.8	18.5	-20.4%	-4.8
Idaho	16.1	16.1	16.6	15.8	15.4	16.2	16.0	15.9	17.4	16.9	18.2	18.5	15.0%	2.4
Illinois	246.0	237.5	245.1	243.7	228.3	233.1	231.8	219.4	232.6	235.4	217.8	205.2	-16.6%	-40.8
Indiana	237.4	234.9	234.6	230.3	207.0	219.3	211.8	197.4	202.6	207.9	188.4	182.9	-23.0%	-54.5
Iowa	80.0	81.2	86.5	90.4	85.3	89.6	86.6	80.6	82.0	82.9	76.8	73.5	-8.0%	-6.4
Kansas	72.8	73.0	80.8	75.4	73.6	73.2	71.3	66.6	70.3	70.5	64.7	62.4	-14.2%	-10.4
Kentucky	152.1	154.4	154.7	152.4	141.9	151.2	150.0	138.8	138.0	139.3	129.8	124.6	-18.1%	-27.5
Louisiana	208.8	220.9	225.6	229.1	212.0	224.5	227.1	215.1	206.2	203.8	206.5	210.3	0.7%	1.5
Maine	23.5	21.6	21.3	19.4	18.7	18.3	17.8	16.1	16.8	16.9	17.1	16.6	-29.6%	-7.0
Maryland	83.4	78.4	78.7	74.9	71.6	70.1	65.3	60.8	59.9	62.2	60.2	57.9	-30.6%	-25.5
Massachusetts	85.9	77.7	81.0	77.9	71.4	72.8	68.9	62.7	66.5	64.6	66.5	64.5	-24.8%	-21.3
Michigan	193.6	182.1	184.0	177.8	166.5	167.0	161.7	155.1	163.7	163.6	163.8	152.6	-21.2%	-41.0
Minnesota	103.1	100.3	101.8	101.4	93.5	93.2	92.8	88.0	90.8	96.0	88.9	89.7	-12.9%	-13.3
Mississippi	64.9	66.9	69.0	65.6	61.4	66.2	61.3	63.3	61.4	64.7	66.0	69.3	6.7%	4.3
Missouri	143.5	141.5	140.5	137.3	131.5	135.4	136.0	128.4	133.8	133.3	123.9	118.3	-17.6%	-25.2
Montana	35.5	35.6	37.1	36.3	32.8	34.7	31.8	30.6	31.9	32.4	32.3	30.6	-13.7%	-4.9
Nebraska	44.4	45.0	45.3	47.4	48.0	50.5	52.9	51.3	54.2	52.8	51.3	48.8	9.9%	4.4
Nevada	50.7	42.1	42.3	41.5	40.0	38.1	34.3	35.1	36.9	37.7	35.7	36.9	-27.3%	-13.8
New Hampshire	21.6	19.7	19.5	19.0	17.3	16.8	16.4	14.8	14.5	15.2	15.4	13.8	-36.0%	-7.8
New Jersey	130.5	123.2	130.8	128.6	111.3	115.5	115.7	105.2	108.8	114.7	113.0	111.4	-14.6%	-19.1
New Mexico	60.0	60.5	59.6	57.1	57.9	53.8	56.2	54.3	53.7	50.6	50.7	48.7	-18.9%	-11.4
New York	212.9	193.9	200.5	190.7	174.7	176.3	166.2	162.9	164.2	172.0	169.9	164.6	-22.7%	-48.3
North Carolina	156.6	150.9	156.7	151.5	135.0	145.0	130.3	123.2	126.7	129.0	122.6	121.2	-22.6%	-35.4
North Dakota	53.1	51.4	53.1	53.6	52.0	52.8	54.3	56.8	57.4	59.4	58.0	54.6	2.7%	1.5
Ohio	275.2	267.6	271.2	264.0	238.7	250.2	238.2	218.5	232.5	234.4	215.4	207.4	-24.6%	-67.8
Oklahoma	108.1	111.3	110.5	113.3	107.5	107.0	108.7	106.1	104.6	105.9	102.0	97.4	-9.8%	-10.6

Table 2. State energy-related carbon dioxide emissions by year, adjusted (2005–2016) (cont.)

million metric tons of carbon dioxide

State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Change (2005–2016) Percent	Change (2005–2016) Absolute
Oregon	41.8	40.9	44.4	43.4	41.5	41.3	37.7	37.5	39.7	38.5	38.6	38.2	-8.7%	-3.6
Pennsylvania	283.3	277.1	279.7	271.7	246.2	257.9	250.5	240.1	249.5	249.1	232.7	218.6	-22.8%	-64.7
Rhode Island	11.4	10.7	11.2	10.8	11.4	11.2	11.2	10.7	10.3	10.8	11.0	9.8	-13.9%	-1.6
South Carolina	87.4	87.7	88.1	85.9	80.3	84.5	80.6	74.1	70.9	75.2	73.6	72.1	-17.5%	-15.3
South Dakota	13.5	13.6	14.1	15.2	15.0	15.3	14.8	15.2	15.7	15.7	14.4	15.1	11.5%	1.6
Tennessee	127.2	129.1	128.8	122.3	103.5	111.1	107.5	101.2	99.6	105.0	101.2	103.6	-18.5%	-23.6
Texas	611.6	620.7	617.4	583.8	549.5	584.3	603.0	599.3	628.2	626.0	626.5	657.4	7.5%	45.8
Utah	67.9	69.1	71.0	70.2	65.4	64.5	65.0	62.4	67.7	65.9	64.3	59.1	-12.9%	-8.8
Vermont	6.9	6.8	6.6	6.0	6.3	6.0	5.9	5.6	5.8	6.0	6.2	6.0	-13.5%	-0.9
Virginia	131.1	124.4	129.6	118.3	107.1	110.2	101.1	99.3	106.4	105.4	104.5	104.8	-20.0%	-26.3
Washington	77.0	74.5	80.0	76.7	74.5	74.4	69.4	69.4	74.1	72.5	74.4	79.3	3.0%	2.3
West Virginia	113.8	113.9	116.0	111.9	90.7	101.8	99.0	93.5	95.6	101.2	93.3	95.1	-16.5%	-18.8
Wisconsin	112.3	104.2	105.9	106.4	97.3	99.6	98.7	91.6	102.1	102.4	101.1	96.1	-14.4%	-16.2
Wyoming	64.0	64.8	67.2	67.7	64.4	65.9	64.7	67.1	69.1	66.2	64.2	61.0	-4.7%	-3.0
United States[1]	5,991.6	5,912.5	6,005.2	5,815.5	5,395.6	5,591.0	5,453.6	5,242.7	5,371.8	5,419.3	5,274.1	5,189.4	-13.4%	-802.2

[1] Source: United States total, *Monthly Energy Review*, September 2018, Section 12

The state values that appear in this table have been adjusted to add to the United States total. See Table 1 for the adjustment factor.

Note: The District of Columbia is included in the data tables and figures but not in the analysis because it is not a state.
Source: EIA, State Energy Data System, and EIA calculations made for this analysis.

Table 6. Per capita energy-related carbon dioxide emissions by state (2005–2016)

metric tons of carbon dioxide per person

State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Change (2005–2016) Percent	Change (2005–2016) Absolute
Alabama	31.4	31.5	31.5	29.6	25.2	27.7	27.1	25.6	25.0	25.4	24.8	23.7	-24.5%	-7.7
Alaska	72.3	68.0	65.0	57.7	54.4	54.5	53.7	52.3	49.1	48.0	49.1	47.0	-34.9%	-25.2
Arizona	16.6	16.6	16.5	16.3	14.7	14.9	14.4	14.0	14.4	13.9	13.4	12.6	-23.9%	-4.0
Arkansas	21.6	22.0	22.2	22.3	21.2	22.5	22.9	22.4	23.1	23.3	19.9	20.9	-3.3%	-0.7
California	10.7	10.9	11.0	10.4	10.0	9.7	9.3	9.3	9.3	9.1	9.2	9.2	-14.1%	-1.5
Colorado	20.6	20.4	20.6	19.8	18.6	18.9	17.9	17.5	17.3	17.2	16.6	16.1	-21.7%	-4.5
Connecticut	12.6	11.7	11.4	10.6	10.1	10.1	9.7	9.5	9.7	9.8	10.2	9.6	-23.9%	-3.0
Delaware	19.9	18.3	19.0	17.7	13.4	12.5	13.5	14.6	14.2	13.6	13.6	14.0	-29.7%	-5.9
District of Columbia	6.9	5.6	5.9	5.3	5.4	5.3	5.0	4.2	4.3	4.6	4.4	4.0	-41.5%	-2.9
Florida	14.6	14.3	14.0	12.9	12.0	12.9	12.0	11.5	11.3	11.4	11.5	11.1	-23.8%	-3.5
Georgia	20.7	19.9	19.7	18.1	16.8	17.7	15.9	13.7	13.5	13.8	13.4	13.2	-36.0%	-7.4
Hawaii	17.7	17.7	18.2	14.5	14.0	13.9	14.1	13.6	13.1	12.9	13.0	12.9	-27.2%	-4.8
Idaho	11.1	10.8	10.9	10.1	9.8	10.2	10.0	9.8	10.7	10.2	10.9	10.9	-1.1%	-0.1
Illinois	19.2	18.5	19.0	18.8	17.6	17.9	17.8	16.8	17.8	18.0	16.7	15.9	-17.2%	-3.3
Indiana	37.2	36.5	36.2	35.3	31.6	33.3	32.1	29.7	30.4	31.1	28.1	27.4	-26.3%	-9.8
Iowa	26.5	26.8	28.4	29.5	27.7	29.0	27.9	25.8	26.2	26.3	24.3	23.4	-12.0%	-3.2
Kansas	26.1	26.0	28.6	26.4	25.6	25.3	24.5	22.7	24.0	24.0	22.0	21.3	-18.2%	-4.7
Kentucky	35.8	36.0	35.8	35.0	32.4	34.3	33.9	31.2	31.0	31.2	29.0	27.9	-21.9%	-7.8
Louisiana	44.9	50.6	50.8	50.9	46.5	48.7	49.0	46.0	44.0	43.3	43.6	44.6	-0.6%	-0.2
Maine	17.5	16.1	15.8	14.3	13.8	13.6	13.2	11.9	12.5	12.5	12.7	12.4	-29.4%	-5.2
Maryland	14.7	13.7	13.7	13.0	12.3	11.9	11.0	10.2	10.0	10.3	9.9	9.6	-34.9%	-5.1
Massachusetts	13.2	11.9	12.4	11.9	10.8	10.9	10.3	9.3	9.8	9.4	9.7	9.4	-28.7%	-3.8
Michigan	18.9	17.9	18.1	17.6	16.6	16.7	16.2	15.5	16.3	16.3	16.3	15.3	-19.4%	-3.7
Minnesota	19.8	19.1	19.3	19.0	17.4	17.3	17.1	16.1	16.5	17.4	16.0	16.2	-18.4%	-3.6
Mississippi	22.0	22.7	23.2	21.9	20.4	22.0	20.3	20.9	20.3	21.4	21.8	23.1	5.0%	1.1
Missouri	24.4	23.9	23.5	22.8	21.7	22.3	22.3	21.0	21.9	21.7	20.1	19.3	-20.8%	-5.1
Montana	37.1	36.8	37.8	36.7	32.9	34.6	31.5	30.0	31.1	31.3	31.0	29.3	-21.0%	-7.8
Nebraska	24.8	25.0	25.0	26.0	26.1	27.2	28.4	27.2	28.6	27.7	26.8	25.4	2.6%	0.6
Nevada	20.5	16.4	16.0	15.4	14.7	13.9	12.5	12.5	13.1	13.1	12.2	12.5	-39.2%	-8.0
New Hampshire	16.4	14.8	14.6	14.2	13.0	12.6	12.3	11.0	10.8	11.3	11.4	10.3	-37.1%	-6.1
New Jersey	14.8	14.0	14.9	14.5	12.5	12.9	12.9	11.7	12.0	12.7	12.5	12.3	-16.8%	-2.5
New Mexico	30.6	30.4	29.5	27.9	28.0	25.7	26.7	25.6	25.4	24.0	24.1	23.2	-24.0%	-7.3
New York	10.9	10.0	10.3	9.8	8.9	9.0	8.4	8.2	8.2	8.6	8.5	8.3	-24.6%	-2.7
North Carolina	17.7	16.7	16.9	16.0	14.1	14.9	13.3	12.4	12.7	12.8	12.1	11.9	-32.9%	-5.8
North Dakota	80.9	77.9	80.2	80.1	77.0	77.1	78.2	79.8	78.3	79.3	75.8	71.8	-11.2%	-9.1
Ohio	23.6	23.0	23.2	22.6	20.4	21.4	20.4	18.6	19.8	20.0	18.3	17.7	-24.9%	-5.9
Oklahoma	30.0	30.5	30.0	30.4	28.5	28.1	28.3	27.4	26.8	27.0	25.8	24.7	-17.5%	-5.2

Table 6. Per capita energy-related carbon dioxide emissions by state (2005–2016) (cont.)

metric tons of carbon dioxide per person

State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Change (2005–2016) Percent	Change (2005–2016) Absolute
Oregon	11.4	11.0	11.8	11.3	10.7	10.6	9.6	9.5	10.0	9.6	9.5	9.3	-18.3%	-2.1
Pennsylvania	22.4	21.8	21.9	21.2	19.1	20.0	19.4	18.5	19.3	19.2	18.0	17.0	-24.0%	-5.4
Rhode Island	10.5	9.9	10.5	10.1	10.7	10.5	10.5	10.0	9.6	10.1	10.3	9.2	-12.2%	-1.3
South Carolina	20.1	19.8	19.5	18.7	17.2	18.0	17.0	15.5	14.7	15.4	14.8	14.5	-28.2%	-5.7
South Dakota	17.2	17.1	17.6	18.8	18.3	18.5	17.8	18.0	18.3	18.2	16.7	17.4	1.4%	0.2
Tennessee	20.9	20.9	20.5	19.3	16.2	17.2	16.6	15.4	15.1	15.8	15.2	15.5	-25.8%	-5.4
Texas	26.4	26.2	25.5	23.6	21.8	22.8	23.2	22.6	23.4	22.9	22.5	23.4	-11.3%	-3.0
Utah	27.2	26.9	26.9	26.0	23.6	22.9	22.8	21.5	23.0	22.2	21.3	19.3	-28.9%	-7.9
Vermont	11.0	10.7	10.5	9.5	9.9	9.4	9.3	8.7	9.2	9.4	9.9	9.6	-12.8%	-1.4
Virginia	17.0	16.0	16.5	14.9	13.3	13.5	12.3	11.9	12.7	12.5	12.3	12.4	-27.2%	-4.6
Washington	12.1	11.5	12.2	11.5	11.0	10.9	10.1	9.9	10.5	10.2	10.3	10.8	-10.5%	-1.3
West Virginia	61.5	61.4	62.4	59.9	48.4	54.1	52.7	49.6	50.9	54.1	50.0	51.7	-16.0%	-9.8
Wisconsin	19.9	18.4	18.6	18.6	16.9	17.3	17.1	15.8	17.6	17.6	17.3	16.6	-16.9%	-3.4
Wyoming	122.5	122.1	123.8	122.1	113.3	115.2	112.4	114.6	117.2	112.0	108.1	103.7	-15.4%	-18.8
Average all states	19.9	19.5	19.6	18.8	17.3	17.8	17.3	16.4	16.8	16.8	16.2	16.0	-20.0%	-4.0

Note: The District of Columbia is included in the data tables but not in the analysis because it is not a state.
Source: EIA, State Energy Data System, and EIA calculations made for this analysis