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HOUSE DEMOCRATIC POLICY COMMITTEE
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House of Representatives
COMMONWEALTH OF PENNSYLVANIA

HOUSE DEMOCRATIC POLICY COMMITTEE HEARING
Topic: Methane and Climate Change
Haverford Township Administration Building – Havertown, PA
January 24, 2019

AGENDA

10:00 a.m. Welcome and Opening Remarks

10:15 a.m. Panel One – Threat of Climate Change:
- Dr. Richard Alley, Professor of Geosciences, Penn State University
- Donald Brown, Scholar in Residence and Professor of Sustainability Ethics and Law, Widener University Commonwealth Law School

11:00 a.m. Panel Two – The Role of Methane Leakage in Climate Change:
- Dr. Tony Ingraffea, Emeritus Professor of Civil and Environmental Engineering, Cornell University
- Peter DeCarlo, Associate Professor of Civil, Architectural and Environmental Engineering, Drexel University
- Rob Altenburg, Director, PennFuture Energy Center

11:45 a.m. Panel Three – Policies to Reduce Methane Leakage:
- Dr. Arvind Ravikumar, Assistant Professor of Energy Engineering, Harrisburg University of Science and Technology
- Leann Leiter, Pennsylvania and Ohio Field Advocate, EarthWorks
- Krish Ramamurthy, Director of Bureau of Air Quality, Pennsylvania Department of Environmental Protection
- Andrew Williams, Director of Regulatory and Legislative Affairs, U.S. Climate and Energy, Environmental Defense Fund

12:45 p.m. Closing Remarks

The Threat of Climate Change and Pennsylvania's Role

Testimony of

Dr Richard B. Alley*
Evan Pugh University Professor of Geosciences
Pennsylvania State University

For the hearing entitled

Methane and Climate Change

Before the

Commonwealth of Pennsylvania House Democratic Policy Committee
Commissioners Meeting Room
Haverford Township Administration Building
1014 Darby Rd, Havertown, PA 19083
January 24, 2019, 10:00 a.m.

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*Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the Pennsylvania State University, the Intergovernmental Panel on Climate Change, the National Academies, the US Climate Change Science Program, or other organizations.

Synopsis. Our use of fossil fuels brings great benefits and costs. Because we are burning fossil fuels roughly 1 million times faster than nature saved them for us, we must find alternatives before too long. Strong scholarship shows that delaying this unavoidable switch, while releasing the carbon dioxide from the fossil-fuel burning, will cause changes in the climate system that are more and more expensive, so that humanity will be better off economically to start very soon to make the transition in a wise way. Furthermore, the relevant scholarship shows that starting soon to make this transition wisely can increase national security, take out insurance against unexpected damaging events, honor the Golden Rule, increase employment, and help preserve endangered species. Although carbon dioxide is the most important issue, methane is also an important greenhouse gas, and control of it can yield notable benefits as well.

Introduction. My name is Richard Alley. I am an Evan Pugh University Professor of Geosciences and Associate of the Earth and Environmental Systems Institute at the Pennsylvania State University. I have authored over 300 refereed scientific papers, and I have made over 1000 public presentations concerning my areas of expertise. My research is especially focused on the great ice sheets of Greenland and Antarctica, their potential for causing major changes in sea level, the climate records they contain, and their other interactions with the environment; I also study mountain glaciers, and ice sheets of the past. I have served with distinguished national and international teams on major scientific assessment bodies, including chairing the U.S. National Research Council's Panel on Abrupt Climate Change (report published in 2002), and serving the U.S. Climate Change Science Program, and the Nobel-Peace-Prize-Winning Intergovernmental Panel on Climate Change (IPCC) in various ways on their Second (1995), Third (2001) and especially Fourth (2007) Assessment Reports. I have had the honor on several occasions of providing requested testimony and briefings to high government officials at the federal as well as state level, including to legislative committees chaired by members of both major political parties, and to executive officials in administrations of both major political parties, drawing on my expertise to provide scientific guidance to those working for the public good. My testimony here is updated from my testimony of November 17, 2010 to the Subcommittee on Energy and Environment of the House Committee on Science and Technology of the United States House of Representatives, and to this Committee on June 7, 2012, December 16, 2013 and March 2, 2015; the consistency of this testimony reflects the consistency of the scientific understanding, which continues to strengthen without fundamentally changing. My advice is nonpartisan, and I am not lobbying for any particular bills or policies; however, I summarize the clear evidence that wise use of our scientific knowledge and related scholarship in policies will make us better off in many ways.

Background on Assessment. Scientists argue. This is a fundamental part of science; ideas that have proven successful through the most tests and challenges are generally the most reliable for our use. Governments have long supported science, because of the great advantages we get from the application of scientific discoveries in medicine, agriculture, manufacturing, and other aspects of our lives. Governments also have developed methods, often called "assessment", to obtain the most useful information from scientists for policy-making and other government functions, while allowing the scientists to go back to doing science including arguing about those results to see if they can be improved further.

Assessment involves asking scientists to volunteer for the public, in the public eye, to summarize the state of science, and to show what is solid, what is still speculative, and what is known to be wrong.

In the United States, scientific assessments are especially done by the U.S. National Academies of Sciences, Engineering and Medicine of Sciences (earlier reports are generally labeled as coming from National Research Council, the operating arm of the National Academies). Established in 1863 by legislative action of the U.S. House of Representatives and Senate, signed into law by President Abraham Lincoln, "The Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art." The Academies assemble panels representing the full range of credible scientific views. As described in many sources (and summarized in Alley, 2011, chapter 5), panels do make recommendations that may serve to reduce research funding in their area, and that may disagree with research thrusts or public statements by panel members, because of the requirement that the panels accurately assess the full scientific knowledge for the public.

The Intergovernmental Panel on Climate Change (IPCC) fulfills a similar role for the world, for climate change. The IPCC was founded in 1988 by the United Nations and World Meteorological Organization to assess the best scientific evidence on climate change. The IPCC issued Assessment reports starting in 1990, 1995, 2001, 2007, and now 2013 (First, Second, Third, Fourth, and Fifth Assessment Reports). The reports are prepared by three working groups, WGI, II, and III, which consider what will happen to climate (WGI), what it means to humans and other living things, and how we might adapt (WGII), and what can we do to reduce or eliminate human-caused climate change (III). The IPCC is not policy-prescriptive, and does not do research; it assesses science. The WGI report is issued first, followed by WGII and WGIII. I served in some ways for the Second and Third Assessment Reports, served more extensively in the Fourth Assessment, but did only a little reviewing and was not otherwise instrumental in the Fifth Assessment Report. I also have served the US National Academy of Sciences and National Research Council in various ways, and was elected to membership in the National Academy of Sciences.

Background on Climate Change and Global Warming. Scientific assessments such as those of the National Academy of Sciences (e.g., National Research Council, 1975; 1979; 2001; 2006; 2008; 2010; 2011; 2013), the U.S. Climate Change Science Program, and the Intergovernmental Panel on Climate Change have for decades consistently found with increasingly high scientific confidence that human activities are raising the concentration of carbon dioxide and other greenhouse gases, especially methane, in the atmosphere, that this has a warming effect on the climate, that the climate is warming as expected, and that the changes so far are small compared to those projected if humans burn much of the fossil fuel on the planet. Consistency between the new IPCC Fifth Assessment Report from WGI and the earlier reports is very high.

The basis for expecting and understanding warming from carbon dioxide, methane and other greenhouse gases is the fundamental physics of how energy interacts with gases in the atmosphere. This knowledge has been available for over a century, was greatly refined by

military research after World War II, and is directly and routinely confirmed by satellite measurements and other data (e.g., American Institute of Physics, 2008; Harries et al., 2001; Griggs and Harries, 2007; Alley, 2011).

Although a great range of ideas can be found in scientific papers and in statements by individual scientists, the scientific assessments by bodies such as the National Academy of Sciences consider the full range of available information. The major results brought forward for the public and policymakers are based on multiple lines of evidence provided by different research groups with different funding sources in different states and nations, and have repeatedly been tested and found to be accurate. Just as a tapestry cannot be destroyed by cutting one thread, the "picture" of climate change is based on an interwoven web of mutually supporting results, such that removing the work of any scientist or small group of scientists would still leave a strong scientific basis for the main conclusions.

Fundamentals. *[The statements in this section and the next are supported by numerous references available through the reports of the US National Research Council, the UN Intergovernmental Panel on Climate Change, and many other sources; I am not providing detailed referencing for most of the material in these two sections for ease of reading, and because those sources are so complete. I will provide the main background on carbon dioxide, and then add additional information on methane.]* Humans burn large amounts of coal, oil and natural gas (fossil fuels), providing roughly 85% of our total energy use. In the United States, fossil-fuel burning provides approximately 100 times as much energy per person as we generate internally from the food we eat, and we use this energy to accomplish things that we enjoy, and that do much good for us. U.S. fossil-fuel use amounts to almost 10 tons per person per year; oxygen is added during burning, releasing almost 20 tons of carbon dioxide per person per year to the atmosphere (these numbers are typical of the last decade or so, fluctuate somewhat from year to year, but remain large).

The carbon dioxide that humans have released by fossil-fuel burning, plus the smaller supply from sources including deforestation and cement manufacture, has raised the concentration in the atmosphere and is moving into the ocean and making it more acidic, although some carbon dioxide is being taken up by processes including reforestation. Human activities have increased the atmospheric concentration by more than one-third since the start of the industrial revolution, after many millennia of naturally stable levels. Ice-core data provide strong confidence that the current level is higher than at any time over the last 800,000 years, and additional data from other sources suggest that the current level has not been reached for millions of years. Various indications in the atmosphere, including changes in the isotopic composition of the carbon dioxide, and the slow drop in oxygen as it is used in combustion, confirm the "bookkeeping" that the rising carbon dioxide comes primarily from our burning of fossil fuels.

The Earth's average temperature is increasing. This is shown by thermometer records as analyzed by researchers working for NASA, NOAA, and other groups. Thermometers outside of cities typically show warming, as do thermometers in the ground, in the ocean, and on satellites as analyzed by different groups. Warming is also indicated by changes in

temperature-sensitive snow and ice, and in the places species live and when they do things during the year.

The warming is not perfectly smooth, and a year may be cooler than the previous year for many reasons, including the effects of a large volcano putting sun-blocking particles in the stratosphere, or a change in the coupled ocean-atmosphere circulation shifting heat into the ocean more rapidly, or a change in the brightness of the sun. Adding the warming-or-cooling effects of these various climate influences to the warming influence of our increasing carbon dioxide and other greenhouse gases gives the observed variability in the warming trend (e.g., Cowtan and Way, 2013). Local cold does not in any way disprove the globally averaged warming; on the 20th of February, 2015, for example, I was supposed to discuss global warming with a local high school that was closed because of cold, but on that day we were almost as warm as regions near the North Pole, while the Arctic, the Northern Hemisphere, the Tropics, the Southern Hemisphere, the Antarctic and the world as a whole remained well above average temperature.

Warming is expected from the known physics of the rising carbon dioxide and other greenhouse gases. Strong scientific effort has been invested in learning whether any other cause could explain the warming. Over the satellite record, the sun's energy output has probably decreased very slightly, and no other natural cause of the observed warming can be found. The pattern of warming, in space and time, is consistent with that expected from the combined effects of the known causes of climate change, including natural and human-produced, with warming from carbon dioxide and other greenhouse gases important.

The accuracy of climate-change projections made over recent decades, and the ability to explain the changes that have occurred and are occurring, contribute to the high scientific confidence that useful projections can be provided for many aspects of the climate system.

(Note that the scientific community cannot accurately predict what decisions policymakers will make, and because humans are so important in the future of the climate, science thus cannot *predict* climate. Instead, *projections* are provided, by estimating the climate response to various possible human paths.)

These projections indicate that if humanity continues to rely on fossil-fuel burning, consumes most of the fossil fuel that is estimated to be practicably available, and releases the carbon dioxide to the air, the coming climate changes will be much larger than those that have occurred to date. Some of this change is already committed—the atmosphere has not experienced the full warming from past human influence because some heat is going into the ocean and to melt ice—but most of the change depends on future emissions of carbon dioxide.

Impacts. Some of the impacts of warming are highly likely, and easy to understand, including an increase in record high temperatures and heat waves, and a decrease in record low temperatures and cold snaps. Because warmer air can "hold" more water (higher equilibrium vapor pressure), rainfall can be more intense when it occurs in a warmer world, which would tend to contribute to an increase in flooding. Expansion of the subtropical dry zones is expected, and summertime drying in many regions, which may increase drought. More

energy will be available, so the top wind speed of hurricanes may increase. Sea-level rise is expected to continue and probably accelerate, in response to expansion of ocean water as it warms, and melting of land ice transferring water to the ocean. Many of our crops suffer heat stress on the hottest days now, even if supplied with enough water and fertilizer, so despite the fertilizing effect of higher carbon-dioxide levels, food production may drop as the warming continues. In general, the changes will cause both "winners" and "losers", but as the changes become large, the losers are expected to dominate the winners. Losers are especially projected to occur among poor people in hot places now, and future generations.

Much scholarship has been devoted to assessing the economic implications, because money spent to reduce global warming now could also be invested in other ways, or used for consumption now. (The reader should recognize that discussions of economics, and of what is or is not a subsidy, as summarized below, are inherently less certain than is our understanding of the warming influence of our greenhouse gases; however, the sources cited here are generally well-respected internationally. There is additional discussion of the social cost of carbon in the WGII reports of the IPCC, with great agreement in the relevant scholarship that there is a significant social cost of carbon.)

Strong evidence exists that humanity will overall be economically better off if the science of global warming is incorporated properly into planning. In particular, studies typically show a notable cost of emitting carbon dioxide that is borne by society rather than directly by those who mine, sell, or burn the fossil fuels. The Interagency Working Group on Social Cost of Carbon, United States Government, in May of 2013, updated estimates of this cost, with advances in scholarship showing the cost to be larger than previously estimated. The Integrated Assessment Modeling techniques used to estimate the social cost of carbon were in many ways developed by the co-recipient of the 2018 Nobel Prize in Economics, William Nordhaus of Yale; this work uses well-accepted economic approaches to show that at least some investment made now in reducing climate change is economically efficient/beneficial.

This social cost of carbon is often considered to be a subsidy for fossil fuels. The International Monetary Fund (IMF, 2013) included the social cost of carbon in their estimate that total subsidies for fossil fuels worldwide in 2011 totaled approximately 2 ½ % of world gross domestic product (GDP), or 8% of total government revenue; this is more than 20 times larger than global renewable-energy subsidies as estimated by the International Energy Agency (2012); the IMF found that the US is the single largest subsidizer of fossil fuels.

In turn, various studies (see, e.g., WGII and WGIII reports of the IPCC) show that this social cost of carbon means that humanity is not following an economically optimal path in regards to energy and environment. Thus, wise actions to remove this subsidy, by pricing the release of carbon dioxide or in other ways, will be economically beneficial, likely with the increase in employment and well-being that goes with an improved economy.

Various recent reports have also looked at the national-security implications of climate change, finding that climate change endangers national security, and thus that slowing and reducing climate changes can improve national security. The Quadrennial Defense Review Report (2010, pp. 84–85) is a good starting point, as is the report of the CNA Military

Advisory Board (2014) of distinguished high-ranking military veterans.

Additional scholarship, much of it summarized by the IPCC WGII and the reports of the National Academies, shows that climate change places rare and endangered species in greater danger. As noted above, these sources also summarize the evidence that the damages from climate change fall disproportionately on poor people, especially those living in hot places, and on future generations. Many groups, including many religious groups, note that this raises strong questions about the Golden Rule.

Tipping Points, and Abrupt Climate Change. A golden retriever leaping to the side will force a canoe to lean, but usually the canoe will remain upright. If an ice chest slides across the seat towards the retriever, this positive feedback will cause the canoe to lean further. In exceptional circumstances a tipping point may be crossed, leading to an abrupt change as the canoe dumps the dog, ice chest, and paddlers into the water.

Much scientific and popular discussion has focused on the possibility that human-caused climate change may force the Earth to cross one of its tipping points. Paleoclimatic history shows clearly that very large, rapid and widespread changes occurred repeatedly in the past (e.g., National Research Council, 2002; 2013; CCSP, 2008). An ice-sheet collapse, a large change in the circulation of the North Atlantic Ocean, a rapid outburst of methane stored in sea-floor sediments, a sudden shift in rainfall patterns, or others are possible even if not considered likely, based on current scientific understanding (CCSP, 2008).

The available assessments, and in particular that of the U.S. Climate Change Science Program (CCSP, 2008), do not point to a high likelihood of triggering an abrupt climate change in the near future that is large relative to natural variability, rapid relative to the response of human economies, and widespread across much or all of the globe. However, such an event cannot be ruled out entirely, and rapidly arriving regional droughts seem more likely than the others considered, with potentially large effects on ecosystems and economies, while a rapid ice-sheet shrinkage raising sea level continues to receive focused research attention.

Projections of warming from a given release of greenhouse gas generally include a best estimate, the possibility of a somewhat smaller or somewhat larger rise, and the slight possibility of a much larger rise; because of the way feedbacks interact in the climate system, very large changes remain possible if unlikely, and are not balanced by an equal probability of very small changes (e.g., Meehl et al., 2007). The possibility of an abrupt climate change gives a similar shape to the uncertainties about damages from whatever warming occurs, with a chance of very large impacts having very large costs, but not an offsetting chance of large benefits.

The new National Academy report (National Research Council, 2013), from a committee that included me, notes that there are many tipping points in ecosystems and economies. Even a small sea-level rise may be sufficient to cause large damages if it causes a storm surge to overtop a levee that otherwise would have been sufficiently high. Even gradual climate change thus can trigger unexpected and costly impacts. In turn, slowing down warming can be seen as taking out insurance against the possibility of such damaging surprises.

Resources. As summarized in many sources, including Alley (2011), nature offers vast, renewable resources, with current technologies capable of extracting far more energy sustainably than now used by humanity. The area of the Earth's surface needed to power all of humanity with these current technologies is small compared to the area now used to feed us. As noted above, wisely beginning the transition to a sustainable energy system is economically as well as environmentally favorable, based on extensive scholarship.

Additional Comment on Methane. Methane is produced in many ways, especially in natural and human-made wetlands (including rice agriculture), in the guts of animals, and during wildfires; methane is also the main constituent of natural gas, and is released from coal beds and from oil operations as well as leakage from natural-gas operations. Per molecule, methane causes more warming than carbon dioxide, in part because methane is less common in the atmosphere so each molecule added gives a greater relative change in the greenhouse effect. Much methane is locked in "clathrate hydrate" ices in permafrost and sea-floor settings, and could be released by changes accompanying a warming climate. Methane is relatively short-lived in the atmosphere, reacting to form carbon dioxide over a decade or slightly less. (In comparison, once the atmospheric concentration of carbon dioxide is raised, it will remain elevated for millennia and longer.)

Methane clearly is valuable as a fuel; thus, methane released to the atmosphere is a lost resource as well as a cause of greenhouse warming. In many places in the US and worldwide, biogas (primarily methane) is collected from landfills, sewage treatment plants, animal manure digesters, or other sources and used as an economic resource (e.g., NREL, 2013).

Because methane is valuable, methane reductions can have a large and rapid effect on global warming, it is often discussed as a target for reducing global warming from rising greenhouse gases, with particular focus on win-win approaches that make money while slowing warming. Note, though, that the very persistent effects of carbon dioxide mean that delaying action to reduce carbon dioxide while addressing methane will allow large and damaging warming extending far into the future (e.g., Pierrehumbert, 2014). Studies generally show that an integrated approach addressing the full scope of human influence on climate including carbon dioxide and methane is more beneficial (e.g., IPCC WG II and WG III reports).

Summary. With high scientific confidence, human release of carbon dioxide from fossil-fuel burning, as well as some other human activities, are having a warming influence on the climate. The influence is projected to become much larger if we continue to burn most of the available fossil fuels. Impacts are expected to become notably negative. Uncertainties are real, but primarily on the "bad" side (with larger, more-costly changes more likely than smaller, less-costly changes). Because fossil fuels are being burned much faster than new ones are made naturally, the current system is unsustainable. Natural, sustainable resources are available to provide much more energy than now used by humanity, and existing technologies can extract this energy, using a much smaller area of the Earth than is now used to feed us. Inclusion of the solid science in planning can lead to decisions that improve human welfare, increase national security, give a cleaner environment, and honor the Golden Rule. Efforts to restrict methane release and use the methane as a resource can have win-win outcomes.

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At

Rep. Greg Vitali's House Democratic Policy Committee Hearing on Methane and Climate Change
Panel 2: The Role of Methane Leakage in Climate Change

January 24, 2019
Havertown, PA

- Climate Change Is Happening and Largely Driven by Anthropogenic Greenhouse Gas (GHG) Emissions
- Carbon Dioxide (CO_2) Is the Primary Anthropogenic GHG, and Its Atmospheric Concentration Is Rising at An Increasing Rate
- Methane (CH_4) Is the Second Most Influential GHG and Its Atmospheric Concentration Is Rising at An Increasing Rate
- Control of Methane Emissions Crucial for Keeping Global Warming Below 1.5°C.
- The Fossil Fuel Sector is the Largest Source of Anthropogenic Methane Emissions in the U.S.
- Methane Emissions from the Oil/Gas Sector in Pennsylvania Are Underestimated
- Methane Emissions from All of Pennsylvania's Oil and Gas Wells, Producing and Abandoned, Comprise 8-10% of Total Annual Anthropogenic Methane Emissions in Pennsylvania, and about 39% of Total Annual Anthropogenic Methane Emissions from the Oil/Gas Sector in Pennsylvania.

1. Climate Change Is Happening and Largely Driven by Anthropogenic Greenhouse Gas (GHG) Emissions

The Intergovernmental Panel on Climate Change (IPCC) in its latest assessment report (IPCC, 2014) states:

> "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen."

and

> "Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century."

2. Carbon Dioxide (CO2) Is the Primary Anthropogenic GHG, and Its Atmospheric Concentration Is Rising at An Increasing Rate

The IPCC finds this about anthropogenic radiative forcing (RF) of well-mixed greenhouse gases (WMGHGs):

> "AR4 assessed the RF from 1750 to 2005 of the WMGHGs to be 2.63 W m–2.

and the radiative forcing of CO_2 alone is:

> "…the CO_2 RF (as defined in Section 8.1) from 1750 to 2011 is 1.82 (1.63 to 2.01) W m–2."

NOAA monitors GHG concentrations and its most recent measurements of CO_2 in the atmosphere are shown in Figure 1.

3. Methane (CH_4) Is the Second Most Influential GHG, and Its Atmospheric Concentration Is Rising at An Increasing Rate

The IPCC finds this about anthropogenic radiative forcing (RF) of methane:

> "The four most important gases were CO_2, CH_4, dichlorodifluoromethane (CFC-12) and N2O in that order."

and the RF of methane is:

> "…the RF for CH4 from 1750 to 2011 is 0.48 ± 0.05 W m–2…"

NOAA monitors GHG concentrations and its most recent measurements of CH_4 in the atmosphere are shown in Figure 2.

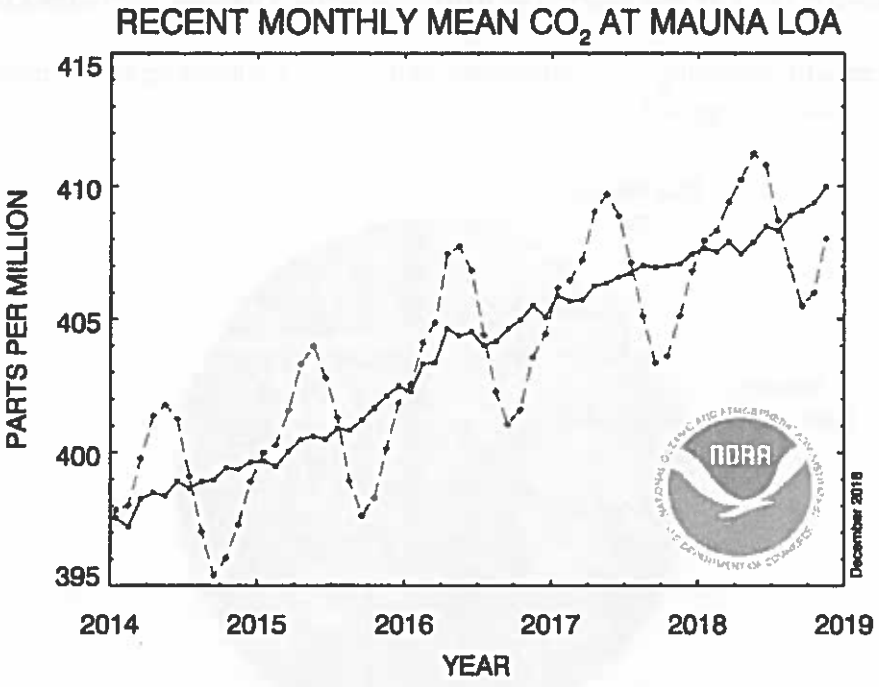

Figure 1. Recent history of CO_2 atmospheric concentration. NOAA (2019a).

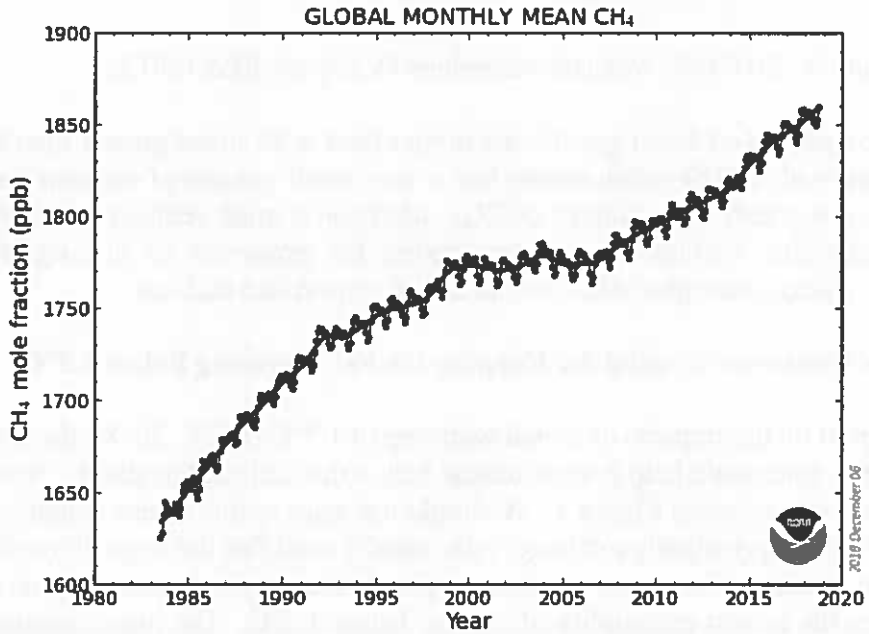

Figure 2. Recent history of methane, CH_4, atmospheric concentration. NOAA (2019b).

Recent research from NASA suggests that 68 percent of this rise in atmospheric methane between 2006 and 2014 came from oil and gas production (Worden *et al.*, 2018).

4. The Fossil Fuel Sector is the Largest Source of Anthropogenic Methane Emissions in the U.S.

The U.S. EPA is charged with reporting GHG emissions in the U.S. Its latest report on methane emissions by source is shown in Figure 3.

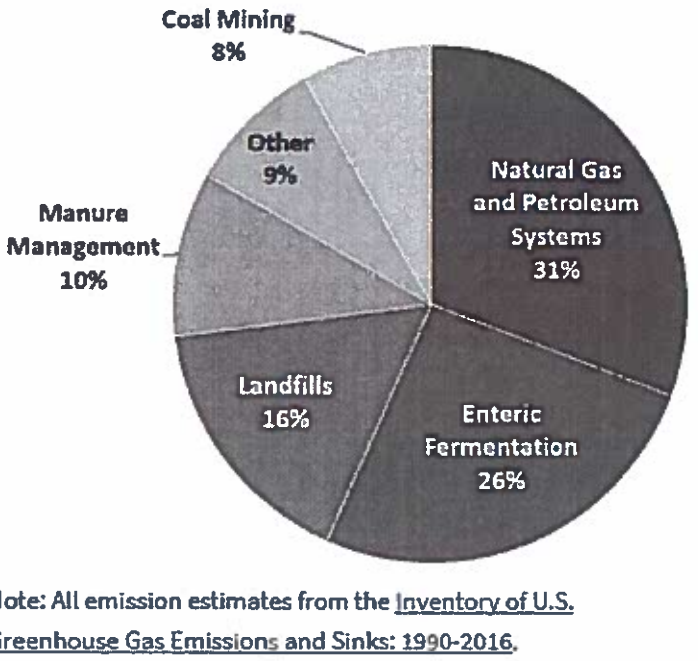

Figure 3. 2016 U.S. Methane emissions by source. EPA (2019)

Methane is the main component of fossil gas. Its warming effect is 98 times greater than CO_2 over a 20-year period (Etminan *et al.*, 2016) which means that a very small volume of methane has the same effect on global warming as a very large volume of CO_2. Methane is often vented into the atmosphere, purposefully and accidentally, without combustion during the processes of drilling, stimulation, production, processing, storage, transportation, compression, export and end use.

5. Control of Methane Emissions Crucial for Keeping Global Warming Below 1.5°C

In its recent Special Report on the impacts of global warming of 1.5°C (IPCC, 2018), the IPCC offered a set of potential scenarios that could help keep warming below that critical threshold. These scenarios are depicted in the rather complicated Figure 4. A simple message in this figure is that reduction of non-CO_2 radiative forcing, i.e. principally methane, substantially modifies the projections shown in the three colored predictive plumes. The plume outlined in pink is the result of no reductions in methane emissions, and produces the lowest probability of staying below 1.5°C. The plume outlined in grey, which involves reduction in non-CO2 forcing after 2030, produces significantly higher probability of staying below 1.5°C. Not calculated but clearly possible is a further increase in this probability if a decrease in non-CO_2 forcing, a decrease in methane emissions, were to occur before 2030.

6. Methane Emissions from the Oil/Gas Sector in Pennsylvania Are Underestimated

The most recent and comprehensive investigation of methane emissions from the U.S. oil and gas sector (Alvarez *et al.* 2018) notes that mean emission rate was 2.3% of total gas production in 2015, and that this rate is 60% higher than reported by the U.S. EPA. Moreover, this rate might be an underestimate (Guglielmi, 2018). The U.S. EPA reports what the states estimate are their methane emissions and gas production values.

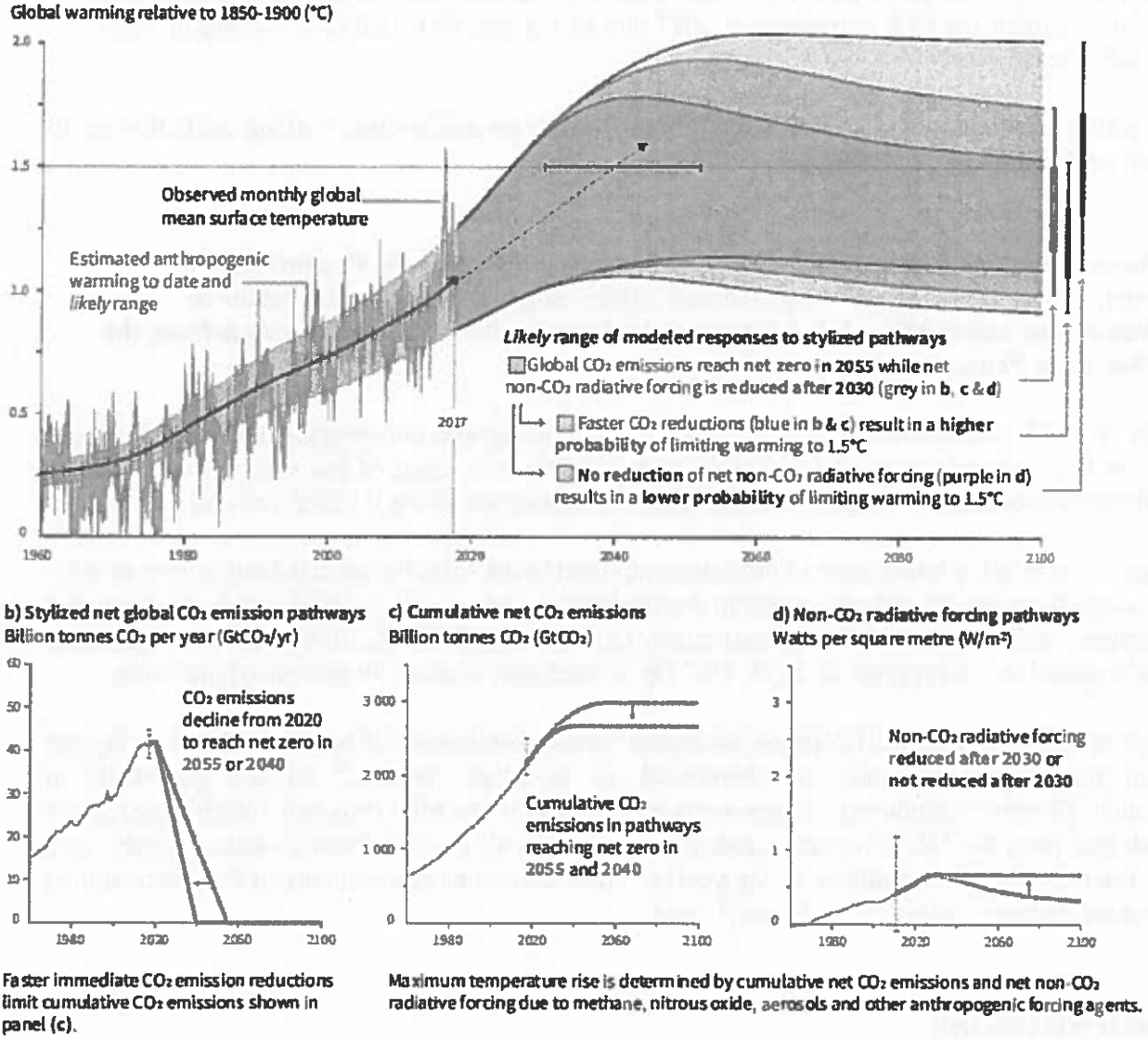

Figure 4. Panel a: Observed monthly global mean surface temperature change and estimated anthropogenic global warming (solid orange line up to 2017, with orange shading indicating assessed likely range). Orange dashed arrow and horizontal orange error bar show respectively the central estimate and likely range of the time at which 1.5°C is reached if the current rate of warming continues. The grey plume on the right of panel a shows the likely range of warming responses, computed with a simple climate model, to a stylized pathway (hypothetical future) in which net CO_2 emissions (grey line in panels b and c) decline in a straight line from 2020 to reach net zero in 2055 and net non-CO_2 radiative forcing (grey line in panel d) increases to

2030 and then declines. The blue plume in panel a) shows the response to faster CO_2 emissions reductions (blue line in panel b), reaching net zero in 2040, reducing cumulative CO_2 emissions (panel c). The purple plume shows the response to net CO_2 emissions declining to zero in 2055, with net non-CO_2 forcing remaining constant after 2030. The vertical error bars on right of panel a) show the likely ranges (thin lines) and central terciles (33rd – 66th percentiles, thick lines) of the estimated distribution of warming in 2100 under these three stylized pathways. Vertical dotted error bars in panels b, c and d show the likely range of historical annual and cumulative global net CO_2 emissions in 2017 and of net non-CO_2 radiative forcing in 2011 from AR5, respectively

Further, neither Alvarez *et al.* nor the EPA estimates include emissions from leaking wells that are in production or that have been abandoned.

7. Methane Emissions from All of Pennsylvania's Oil and Gas Wells, Producing and Abandoned, Comprise 8-10% of Total Annual Anthropogenic Methane Emissions in Pennsylvania, and about 39% of Total Annual Anthropogenic Methane Emissions from the Oil/Gas Sector in Pennsylvania.

During 2014-2017, average methane emissions from producing and non-plugged abandoned oil and gas wells in Pennsylvania were 21.1 Gg (Gigagrams). This is a result of analysis of data collected through the new Mechanical Integrity Assessment (MIA) program of the PADEP (2018a).

A measure of the relative importance of emissions reported to the MIA Program is their impact on total CH_4 emissions from the oil and gas sector in Pennsylvania. The overall methane emissions from this source category in 2015 amounted to approximately 123,081 tons (PADEP, 2018b). The average yearly total flow reported to the Program in 2015, 19.7 Gg of methane, is about 39 percent of this value.

For comparison, Kang *et al.* (2016) report estimated methane emissions of between 40 and 70 Gg per year from hundreds-of-thousands of abandoned, or so-called "legacy," oil and gas wells in Pennsylvania. Therein "abandoned" means wells not included in the MIA Program. Combining Kang's result with that from the MIA Program yields emissions from all wells in Pennsylvania, "legacy" and not, of at least 61 Gg and as much as 91 Gg yearly. Such emissions represent about 8–10% of annual anthropogenic methane emissions in Pennsylvania.

RECOMMENDATIONS

As Pennsylvania moves forward with its Methane Reduction Strategies (PADEP, 2018c), regulators and lawmakers would be well advised to focus on the findings of the MIA Program and on investigations such as those of Kang *et al.* All wells eventually need to be plugged, and some might need substantial remediation before plugging, or re-plugging in the future. In cases where no viable responsible party can be identified for a well, the PADEP's Bureau of Oil & Gas Planning and Program Management assumes responsibility for well plugging: the wells become wards of the taxpayers of Pennsylvania. The state cannot be proud of much of the "legacy" of coal development in the state, and it now runs a high risk of making such an adjective even more ironic with methane leaks from existing,

and perhaps soon-to-be, legacy oil and gas wells. Using inflation-adjusted plugging cost information, and assuming, for example, that 200,000 existing legacy wells may require plugging at some point in time, the PADEP estimates that $8.4 billion are needed to address this significant environmental challenge. Please note that so long as more new wells are put into production, and the risk of these wells also becoming "legacy" leaking wells continues to exist, this source of substantial methane emissions will be never ending.

Approaches to address this problem of leaking wells that are least likely to increase costs to the taxpayer are needed:

- Substantially increase well bonding requirements that originate in the 1984 Oil and Gas Act.
- Mandate usage of the Marcellus Legacy Fund to address the "legacy" leaking well problem.
- Using new data from the MIA program, identify the relatively small number of wells that are emitting most of the methane, and empower the PADEP to require operators of these wells to fix the leak or plug the well now, to avoid ongoing emissions and the likelihood that such wells will be "passed on" to operators with fewer resources and/or desire to fix the problem.

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Remarks by Peter DeCarlo, Ph.D. to the Democratic Policy Committee Hearing for the Commonwealth of Pennsylvania

January 24, 2019

Hello, my name is Peter DeCarlo, and I'm an atmospheric scientist and associate professor of environmental engineering and chemistry at Drexel University. I'm here to talk about methane leakage in Pennsylvania and the role of that in climate change. Let's start with the "best case" for natural gas in this state, zero leakage. Under that scenario, natural gas combined cycle power plants emit roughly half of the carbon dioxide (CO_2) per MW than a coal fired power plant. This is where those 30% reduction in CO_2 emissions numbers for the Commonwealth of Pennsylvania come from. Unfortunately, those numbers do not tell the whole story, since they do not include the methane that leaks to the atmosphere as it is produced and transported to the place in which it is burned. This is an important omission since molecule-per-molecule methane is 56 times more powerful at warming the climate than CO_2 over a 20-year time horizon. Let's also not forget in this discussion that renewables and nuclear power have no CO_2 emissions or methane leakage at their point of power production.

So how do we as scientists and engineers understand leakage? We know there is leakage. We can measure it, and occasional pipeline explosions are poignant reminders that natural gas is a dangerous commodity. Let's go back to the comparison between natural gas and coal. Natural gas is more efficient at making electricity than coal in terms of CO_2 emissions, but at what methane leakage rate does that efficiency disappear? The estimate is that at approximately 3% leakage the use of natural gas has no climate benefit compared to coal. Nationally, the most recent numbers are 2.3%, and this means there is still some benefit, although it is dwindling and smaller than it could be. Again, don't forget that renewables and nuclear do not have CO_2 emissions or methane leakage from power production.

Measurement of methane leakage can generally be categorized in 2 ways, what we call "Bottom up" and "top down" methods. Bottom up estimates involve making measurements of leakage at the facility (think well pad), or even equipment level. Obviously, given the scale of the oil and gas industry, we cannot measure every piece of equipment, nor does a single piece of equipment have the same leakage rate over its lifetime. Rather this subset of data can be scaled up to estimate the total leakage, assuming that the sampled sites were representative of the average. Top down estimates use measurements of total methane emissions for a region, by looking at upwind and downwind concentrations of methane and calculating how much methane must have been emitted to increase the concentrations. This method gives a total emission number for a region, but does not identify the individual sources. Now I've greatly simplified the process for both of these methodologies, but they each provide some measure of methane emission. The bottom up methodologies can be compared site to site to the emission inventories compiled by DEP from information submitted by industry. In virtually all comparisons, the measurements exceed the leakage rates for methane reported by industry. The top down methodology provides a comparison to the sum-total of all reported methane emissions in the emission inventory. This comparison also indicates that the emission inventory is significantly under-predicting the total emission of methane in Pennsylvania.

My own research in this area very clearly shows this to be the case. In 2012 my research team measured the atmospheric enhancement of methane in NE Pennsylvania of approximately 50 parts per billion. Similar measurements three years later this enhancement of methane in the same region was 150 parts per billion, indicating leakage of methane *increased by 300%* similar to the increase in natural gas production over this time. The reported emission inventory for this region over that same time span suggested that there was a 30% *decrease* in methane emissions. Fundamentally, this discrepancy is almost certainly due to the way in which emission inventories are determined. They are simply not an accurate assessment of real-world emissions (note that similar discrepancies exist for calculating vehicle emissions as well, so this is not isolated to oil and gas). The bottom-line is that without adequate monitoring and measurement we do not have accurate numbers on methane leakage in this state. This hampers our ability to accurately assess the gains or losses with respect to climate.

So where do we improve things? Clearly, additional infrastructure for monitoring at well pads, compressor stations, and other facilities is required if we do want to truly understand this issue. Measurements of leakage from buried infrastructure such as pipelines are absolutely required. From my experience, pipeline infrastructure is very difficult to measure due to right-of-way issues, and limited access to pipeline routes. Exacerbating this issue is that there is currently there is no single authority to regulate all pipelines in the state, and a significant amount of unregulated class 1 pipeline exists (an estimated 12,000 miles of pipe). Leaving poor oversight of this potential source.

Fundamentally, a fair and accurate accounting of all of the methane leakage in the Commonwealth is an extremely difficult but important task if we continue to produce natural gas at the rate we are currently producing it. Given what we know about climate change and the role of methane in exacerbating climate change, we must also ask if this is what we truly want to be investing our resources in?

Thank you.

Testimony of Robert C. Altenburg
before the
Pennsylvania House Democratic Policy Committee
Haverford, PA
January 24, 2019

Good morning Chairman Sturla and members of the committee. My name is Robert Altenburg and I am the director of the Energy Center at Citizens for Pennsylvania's Future (PennFuture). I would like to thank you for giving me the opportunity to speak today on the issue of natural gas and climate change. I hope to make one main point today: we can't drill our way to a healthy climate.

A meaningful response to climate change is going to take significant work. The Intergovernmental Panel on Climate Change's (IPCC) October 2018 special report finds that to limit global warming to at or below 2□ requires at least a 25% decline in emissions from a 2010 baseline by 2030 and net-zero emissions by 2070. A more aggressive program to limit global warming to 1.5□ would require a 45% decline in emissions between 2010 and 2030 and net zero by 2050.

While the absolute amount of carbon pollution we need to reduce is important, it's also worth looking at where the pollution is coming from and what we can effectively influence. In Pennsylvania, our carbon pollution can be roughly broken down into thirds with a little over a third from electricity generation, a third comes from transportation sources, and a third from industrial, commercial, and residential uses. If we are going to reach our goals, we need to address all these categories.

For our purposes here we can temporarily set transportation issues aside. Not because the issues are not important, but because federal law limits what Pennsylvania can do in that area, and because only about 3 percent of the natural gas used in the U.S. goes to transportation. By comparison, a few years ago natural gas surpassed coal as the largest source of generation on our power grid and it continues to grow.

Most of us have probably heard the claim that we are not only on track to meet our goals, but that our progress is in large part because of our expanded use of natural gas. While that statement is built on a kernel of truth, this is one of those cases where past performance is no guarantee of future results.

As we sit here today, Data from the U.S. Energy Information Administration (EIA) suggests we've already reduced carbon emissions by 17% from 2010 levels and, if the Bruce Mansfield coal plant closes in 2021 and the Brunner Island plant converts to natural gas as planned, all else remaining the same we could reduce our emissions up to 21%. That sounds like progress, and most of the improvement can be fairly attributed to relatively cheap new natural gas generation replacing old coal plants, but the pathway to our carbon goals is getting harder with every step.

Those new gas plants might produce half the carbon pollution of coal, but that doesn't account for methane leakage and replacing any one fossil fuel with another has diminishing returns. Bruce Mansfield is the largest remaining coal plant in Pennsylvania and, once it and Brunner Island are not longer burning coal, there will only be five of the large (>0.5 GW) coal plants left: Homer City, Conemaugh, Keystone, Montour, and Cheswick.

If also we lose the Three Mile Island (TMI) and Beaver Valley nuclear plants as planned and their lost generation is replaced with natural gas, our reductions would be closer to 18%. At that point, even replacing the remaining five largest coal plants with gas generation might not be enough to get us to the 25% target, and

moving beyond 2030 targets will be even harder. We will have traded a fleet of old coal plants that are already at or near their designed lifespan for much newer resources that will likely still be there in 2050 and maybe even in 2070 when we need to be working on getting to net-zero.

The short-term successes from replacing coal in the electric generation sector also masks another issue: carbon pollution from industrial and commercial sources in Pennsylvania has been increasing. Even accepting the natural gas industry's self-reported leakage data, the combined emissions from natural gas plants and the leakage from the gas industry might exceed our emissions from coal as early as next year. If actual leakage emissions are much higher than claimed as some reports suggest, we might already have crossed that line.

The natural gas industry is going to be part of the economy in Pennsylvania for many years, but we are no longer in an era where we can ignore pollution as a natural consequence of economic growth. Avoiding the worst impacts of global warming requires that we remain under a set carbon budget and that means that any additional emissions from the natural gas sector are emissions we will need to account for later or face the costs.

In this and future legislative sessions, we expect to see proposals that subsidize the natural gas industry, promote expansion of markets for gas, and shield the industry from oversight. These will, no doubt, be couched in terms of short-term economic benefits, but such actions will also create a harder pathway for all of us in the future--we need to understand those costs too.

While it is appropriate for the Commonwealth to invest in industries that bring jobs and economic growth, fossil fuel resources come with a risk of being expensive stranded assets. In many cases, investing instead in clean renewable generation or energy efficiency will be the better choice.

Arvind P. Ravikumar
Harrisburg University

PA House Democratic Policy Committee Hearing – Methane and Climate Change

Testimony of Arvind P. Ravikumar
Assistant Professor in Energy Engineering
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Good morning, Chairman Sturla, Representative Vitaly and members of the House Democratic Policy Committee. Thank you for hosting us today and for your interest in addressing methane emissions from Pennsylvania's oil and gas industry.

My name is Arvind Ravikumar, and I'm an assistant professor at the Harrisburg University of Science and Technology. I run the sustainable energy development lab[1] at the University where we work on addressing methane emissions from the well-head to the burner tip. I recently completed my post-doctoral work at Stanford and received my doctorate in Engineering from Princeton University.

Pennsylvania is the second largest producer of natural gas in the United States. Beyond significant economic benefits, shale gas has helped reduce carbon pollution from the power sector by replacing high-emitting coal plants with gas-fired plants. Projections of energy demand in the US and around the world show an increasing role for natural gas to complement the growth in renewables. Yet, the growth of the industry comes with its own set of environmental impacts, chief among which are methane emissions. Methane is a powerful greenhouse gas that contributes significantly to climate change, especially in the short term. Therefore, the **key to developing a sustainable natural gas industry is to eliminate methane emissions.**

Getting to zero emissions – which has been difficult or expensive in the past – is now possible, thanks to rapid technological innovation[2]. New technologies now make it more cost-effective than ever before to reduce methane emissions. Indeed, what's limiting effective methane mitigation in the state is not technical feasibility. It is regulatory uncertainty. While the Department of Environmental Protection (DEP) under the leadership of Gov. Wolf has taken encouraging steps recently to address methane pollution, more can be done. Here I will outline **three cost-effective regulatory actions** based on my research at Stanford and Harrisburg that can help further reduce methane emissions at lower cost.

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Arvind P. Ravikumar
Harrisburg University

Action 1: Develop rules to incorporate new technology in leak detection and repair programs

Existing regulations in Pennsylvania require the use of optical gas imaging systems for leak detection in semi-annual or quarterly surveys. This method is often done manually, is slow, and expensive at scale[3]. To address this problem, many start-up companies are developing mobile methane detection systems on platforms such as trucks, drones, planes, and even satellites that promise faster and more cost-effective leak detection. Recently, I led a research program called the **Stanford/EDF Mobile Monitoring Challenge**[4] that tested the performance of 10 different technologies for use in leak detection and repair programs. We found that many of these new technologies are effective at detecting leaks, are much faster than on-foot ground surveys, and likely more cost-effective. For example, a ground survey crew of two people can visit 5 – 6 sites per day, while a truck- or a plane-based system can visit up to 10 times more. Furthermore, recent work in our group and elsewhere show that **methane emissions are dominated by a few, very large leaks or super-emitters**[5]. Finding and fixing these super-emitters should be top priority. This requires that leak detection surveys much be fast, frequent, and cost-effective.

Operators are reluctant to take advantage of these new systems because they are not formally approved by regulators. I, along with colleagues from the industry and other universities, am working with state regulators in Colorado and California to **develop a formal approval framework for new methane detection technologies**[6]. In a recent workshop we organized that brought together scientists, oil and gas operators, and regulators to discuss this issue, Pennsylvania DEP was notably absent. Not only is this a vital opportunity to further reduce the costs of methane mitigation, it is also an economic advantage that will bring **hundreds of local jobs** to the state. I myself have personally worked with about 15 companies developing innovative systems for leak detection – many of them are small businesses who are developing their platforms here and are creating local jobs[7]. There are many more. Embracing this opportunity will **promote innovation, create jobs, protect the environment**, and position Pennsylvania as a leader in sustainable energy development.

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Arvind P. Ravikumar
Harrisburg University

Action 2: Address methane emissions directly, even in existing wells

Recent proposals by DEP have sought to address methane emissions from existing wells indirectly through limits on VOC emissions[8]. This is a mistake. Although methane and VOCs are correlated, there is significantly more methane in Pennsylvania because Marcellus is a dry gas play. Directly targeting the most significant issue, in this case methane emissions, will ensure the future sustainability of the industry. Furthermore, many of the new technologies for leak detection I just described focus on detecting methane, not VOCs. Therefore, a regulatory regime that does not target methane directly will not be able to take advantage of the latest, cost-effective approaches to leak detection, as is being done in Colorado and California.

Action 3: Develop rules to limit or eliminate venting, especially from tanks

Venting is a significant contributor to total methane emissions. Addressing vented methane – from pneumatic systems, well completions, compressor stations, and tanks – is critical to solving the methane challenge. While this wasn't possible before due to technical feasibility or cost concerns, it is now. New companies are developing low-cost, low-bleed solutions that effectively eliminate vented emissions[9]. The cost of existing operations to limit venting including the use of vapor recovery units, green completions, and using electrically-driven pneumatic systems are rapidly falling. Recent research has shown that tanks are one of the biggest sources of methane emissions – often due to issues such as an open thief hatch that can be fixed easily[10]. Ensuring that tank-related issues are addressed through a comprehensive tank monitoring program is vital to reduce a major source of methane.

Pennsylvania can and should be a leader in the sustainable development of the natural gas industry. Rapid technological innovation in methane detection has now made it possible to achieve a near-zero methane emissions industry. A stable and effective regulatory regime will also give the industry the necessary space to invest in sustainable, low-emission operations. **Allowing for the use of the most cost-effective solutions and adopting rules to limit or eliminate venting across natural gas facilities will position the industry for a sustainable, climate-conscious future.** At a time when federal regulations are in flux, Pennsylvania can decisively demonstrate that economic development and environmental protection can go hand in hand.

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EARTHWORKS

Democratic Policy Committee
Hearing on Methane and Climate Change

Haverford Township Administration Building
1014 Darby Rd, Havertown, PA 19083

January 24, 2019

Representative Vitali and Committee Members:

Good morning. My name is Leann Leiter. I am the Earthworks Field Advocate for Pennsylvania and Ohio. Earthworks is a national nonprofit organization committed to protecting communities and the environment from the impacts of mining and energy development while seeking sustainable solutions.

I live in Washington County—the most heavily-fracked county in this state—so I am both professionally and personally familiar with the range of impacts of the gas industry on air, water, land, and quality of life.

Earthworks responds to community requests to document air pollution at well pads, compressor stations, and other facilities. We do so with staff trained and certified to use industry-standard optical gas imaging (OGI) cameras—the same approach used by industry and federal and state regulators.

Across the state, we see pollution at both older conventional wells and newer, unconventional wells. We also see significant permitted pollution at countless processing plants and compressor stations. The pollution is the result of both decades of neglect at many sites and the ever-expanding network of new gas infrastructure.

For example, we have seen problem after problem at a newer unconventional well in Washington County—including improperly vented emissions and a tank hatch left ajar, releasing uncontrolled pollution—problems that went unnoticed for months even though residents complained, workers were routinely onsite, and state inspections took place. We recently documented leaks and unchecked emissions at older conventional wells in the Allegheny National Forest[1]; DEP's own records indicated the wells had gone up to five years without an inspection. And over the past three years, we have repeatedly documented an improperly operating flare at a processing plant in Butler County.

This OGI video evidence of air pollution is visual, irrefutable proof of the need for strong regulations for the oil and gas sector in Pennsylvania. I invite each of you to join me in the field to see for yourselves.

Rules need to be complete, comprehensive, and consistent. It is crucial that they address both toxic pollutants and ozone-forming, climate-disrupting methane, and do not exempt the conventional industry from these pollution controls.

- **New rules must regulate methane directly**

It is important to clarify for this discussion that "leakage" figures in studies represent both accidental/unintentional leaks due to mechanical and operational problems *and* releases of pollution into the atmosphere during "normal operations," including from stacks, engines, and other combustion sources. Given this, any regulations to control methane and VOC releases must be strong and comprehensive enough to reduce emissions from throughout the gas development chain.

Dedicated to protecting communities and the environment from the adverse impacts of mineral and energy development while promoting sustainable solutions.

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[1] https://earthworks.org/blog/leaky-oil-wells-in-allegheny-national-forest-prove-pennsylvania-needs-conventional-drilling-rules-more-than-ever/

EARTHWORKS

The draft rules presented by the DEP last month are based on the federal Control Technique Guidelines (CTGs), which encourage voluntary measures by operators to control Volatile Organic Compounds (VOCs). Guidelines based on optional controls should therefore be used only as a floor, not a ceiling, with regard to what DEP can and should require operators to do to limit VOCs and address the specific climate impacts of methane.

Importantly, the composition of Pennsylvania's gas resources varies widely, with varying proportions of methane and VOCs, so both must be covered by regulation. The same variability applies to different stages of gas development, including liquids separation, processing, compression, pigging, and metering. The publicly available draft of the DEP rule, however, proposes to only regulate VOCs, treating any subsequent methane mitigation as a co-benefit, rather than as a quantifiable, critical goal.

Reigning in methane is essential, because methane is a greenhouse gas 86 times more powerful than carbon dioxide over the critical two decades that the scientific community says we have to curb global climate change. Mitigating methane emissions will also help protect the health of Pennsylvanians because methane is a precursor for ground-level ozone, which leads to asthma attacks and other respiratory ailments.

In fact, according to the latest National Climate Assessment[2], "The magnitude of the human health benefit of lowering ozone levels via methane mitigation is substantial and is similar in value to the climate change benefits." The entire state of Pennsylvania is in the Ozone Transport Region and several counties, including heavily drilled ones, do not currently meet the federal standard for the pollutant[3].

Pennsylvania can go much further to control pollution from its hundreds of thousands of existing oil and gas sources. Our neighboring state of Ohio, for example, recently set an admirable precedent by stating that federal OOOOa rules would be the basis for state rules on new and existing oil and gas operations. DEP should consider OOOOa and look for any aspects that may provide more robust pollution protections than the CTGs, such as covering additional sources and processes, and of course because the federal rules specifically set controls on methane.

- **New rules should not exempt low producers**

Both conventional and unconventional wells release methane and VOCs, so the reporting, inspection, and repair schedule used to address that pollution should be consistent. Low rates of well production should not exempt operators from these requirements, because data shows that production levels do not necessarily correlate with emissions levels. We have documented significant leaks even at wells reporting *no* production.

DEP's draft rule effectively exempts the entire conventional gas industry because of applicability thresholds based on production amounts. One study by Carnegie Mellon estimates that because of poor maintenance and sheer number, the conventional industry may release even more methane per unit of production than the unconventional industry[4]. The conventional industry, according to Environmental Defense Fund estimates[5], emits almost 270,000 tons per year of methane that goes unreported and unaccounted for. That figure is *more than double* the annual amount of methane pollution reported by the unconventional industry.

Earthworks recommends that DEP lower or remove the applicability threshold based on production in order to include all sources of pollution.

Dedicated to protecting communities and the environment from the adverse impacts of mineral and energy development while promoting sustainable solutions.

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[2] https://www.globalchange.gov/nca4
[3] https://www.dep.pa.gov/business/air/baq/regulations/pages/attainment-status.aspx
[4] Omara, Sullivan, Li, et. al. Methane emissions from the conventional and unconventional natural gas production sites in the Marcellus Shale Basin. *Environmental Science and Technology*, 216. https://pubs.acs.org/doi/10.1021/acs.est.5b05503.
[5] http://www.edf.org/pa-oil-gas/#/air-emissions

EARTHWORKS

- **Pennsylvania should transition away from oil and gas development**

Strong regulations and their enforcement are critical to protect climate and health. But the fact will remain that all industry pollutes, and there are no leak-proof well sites, no emission-less compressors. Yet permits for new wells and facilities continue to be issued, and Pennsylvania is staking its future on a non-renewable resource and an inherently polluting industry.
This influx of new oil and gas extraction and development needs to stop. Pennsylvania cannot maintain its cherished qualities and continue to be a desirable place to live and do business while drastically diminishing its air quality. It cannot honor the Governor's recently-announced climate commitment by promoting the expansion of the gas industry or exempting its low producers. It cannot promise its residents *good* jobs in the most dangerous US industrial job sector; it cannot offer *lasting* jobs by repeatedly investing in an industry broadly forecasted as financially and logistically doomed.

...

There are hundreds of thousands of sources of oil and gas pollution in Pennsylvania, and more than 1.5 million residents live within a ½ mile health threat radius of these industrial operations[6]. In addition, the urgency of climate change demands we take determined action, as Governor Wolf recently acknowledged.

I urge you all to support strong new rules as they advance through the rulemaking process. DEP must be allowed to adopt and enforce measures to effectively control methane and other harmful pollution.

But your advocacy for the climate and for the health of Pennsylvanians should not end there. As a resident of Pennsylvania's gas patch and as a researcher who continually witnesses pervasive air pollution across our state, I ask that you also consider the fact that to protect the climate and health, Pennsylvania needs to start shifting away from a dependence on fossil fuels and toward renewable energy.

I thank each of you for exercising your responsibility as an elected official to protect our Commonwealth.

Sincerely,

Leann Leiter
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Additional References:

Earthworks OGI Program: cep.earthworks.org

Earthworks OGI footage from Pennsylvania: bit.ly/CEP-PA

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[6] https://oilandgasthreatmap.com/threat-map/pennsylvania/

Testimony of

Krishnan Ramamurthy, Director of the Bureau of Air Quality

Department of Environmental Protection

Before the House Democratic Policy Committee on

Methane and Climate Change

January 24, 2019

Good morning, Representative Vitali and members of the Committee. My name is Krishnan Ramamurthy, and I am Director of the Bureau of Air Quality in the Department of Environmental Protection (DEP). I would like to thank you for the opportunity to appear before you today to discuss policies to reduce methane leakage.

On January 19, 2016, Governor Tom Wolf launched a strategy to reduce emissions of methane, a greenhouse gas that contributes to climate change, and has been implicated in health risks. The methane reduction plan is designed to reduce emissions from natural gas well sites, compressor stations and along pipelines, and will protect the environment, reduce climate change, and help businesses reduce the waste of a valuable product. Methane, the primary component of natural gas, has been identified by the U.S. Environmental Protection Agency as the second-most prevalent greenhouse gas emitted in the United States from human activities. With federal estimates that the natural gas and oil industries account for a quarter of U.S. methane emissions, reducing methane leaks from the oil and gas sector is one of the essential steps needed to reduce global greenhouse gas emissions and reduce the impacts of climate change.

According to the 2017 Pennsylvania Greenhouse Gas Inventory report, between 2000 and 2014 methane emissions from natural gas and oil systems increased approximately 71%. However, according to 2014 methane emission estimates included in the report, the oil and gas sector represented only 21% of the total methane emissions. DEP emissions inventory data from natural gas industry sources in Pennsylvania shows a general increase in emissions from 2013, peaking in 2015, with a slow decline until 2017. The increase in reported emissions is due primarily to the increase in number of facilities reporting. The slow decline since the peak in 2015 is due to decreases in reported methane emissions per facility. Mid-stream compressor stations have decreased to an average of 97 tons per facility from an average of 114 tons per facility; unconventional well facilities have decreased to an average of 11 tons per facility from an average of 13 tons per facility.

Governor Wolf's methane reduction strategy has four components. The first is to reduce leaks at new unconventional natural gas well pads by developing a general permit for sources at new or modified

unconventional well sites and remote pigging stations (GP-5A), requiring best available technology (BAT) for equipment and processes, better recordkeeping, and quarterly monitoring inspections. The second is to reduce leaks at new compressor stations, processing plants, and transmissions stations by revising the general permit for sources at natural gas compression, processing, and transmission facilities (GP-5), to update BAT requirements and apply more stringent leak detection and repair (LDAR) requirements. The third is to reduce leaks at existing oil and natural gas facilities by developing a regulation for existing sources for consideration by the Environmental Quality Board (EQB). The fourth is to reduce emissions along production, gathering, transmission, and distribution lines, establishing best management practices including LDAR programs.

After extensive public participation, DEP finalized GP-5 and GP-5A and revised Exemption 38 of the Air Quality Permit Exemptions list on June 9, 2018, which became effective on August 8, 2018, thereby meeting the first two goals of the Governor's methane reduction strategy. Methane emissions will be reduced for all new sources permitted under the GP-5 and GP-5A. This is due to common-sense controls being implemented as part of the BAT determination for sources such as glycol dehydration units, storage vessels, natural gas-driven pneumatic pumps, and pigging operations.

The third goal of the Governor's methane reduction strategy is currently in the development process and coincides with the United States Environmental Protection Agency's (EPA) *Control Techniques Guidelines for the Oil and Natural Gas Industry* (CTG) to address VOC emissions from existing sources, which was published on October 27, 2016. Because of the CTG, DEP is required to develop a rule under the Clean Air Act (CAA).

On March 9, 2018, EPA requested public comment on a potential withdrawal of the CTG based on a request for reconsideration of the recently finalized New Source Performance Standard (NSPS) in 40 CFR Part 60 Subpart OOOOa. EPA's concern with the CTG was that the NSPS in Subpart OOOOa were being reconsidered. EPA proposed amendments to the NSPS requirements based on the reconsideration on October 15, 2018. Some of the amendments include the reduction in monitoring frequency in required leak detection and repair (LDAR) programs, changes in natural gas-driven diaphragm pump requirements, and changes in the certification requirements related to professional engineers. DEP submitted a comment letter opposing the proposed rule to withdraw the CTG, as well as a comment letter providing recommendations for the reconsideration amendments. Despite the potential withdrawal of the CTG, DEP is continuing its rulemaking process as required. As originally proposed as part of the Methane Strategy, the proposal would place controls on volatile organic compound (VOC) emissions which in turn reduces methane emissions, since both VOC and methane are found in field gas in oil and gas operations. DEP adopted EPA's Control Technique Guidelines (CTG) recommendations except for placing stronger controls on storage vessels and fugitive emissions.

DEP's LDAR requirements have been recognized as an alternative means of emission limitation for Subpart OOOOa and have been incorporated into the preliminary draft proposed rulemaking that was presented as an information item to the Air Quality Technical Advisory Committee (AQTAC) on December 13, 2018. Enhancements from the CTG recommendations include stronger controls on

storage vessels and fugitive emissions. Other potential changes to the NSPS have also been incorporated into the draft proposed rulemaking by DEP in anticipation of the amendments to Subpart OOOOa. The preliminary draft proposed rulemaking was also presented to the Small Business Compliance Advisory Committee (SBCAC) yesterday, January 23, 2019.

The next step will be to present the draft proposed rulemaking to AQTAC, the Citizens Advisory Council (CAC), and the SBCAC for a vote whether to concur with DEP's recommendation to present the draft proposed rulemaking to EQB for consideration. After the rulemaking is adopted by EQB, DEP will provide a 60-day public comment period and the opportunity for public hearings.

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House Democratic Policy Committee Hearing

"Policies to Reduce Methane Leakage"

January 23, 2019

Testimony of Andrew Williams

Good morning and thank you Chairman Sturla, Chairman Vitali and all the members of the House Democratic Policy Committee for the opportunity to speak today. My name is Andrew Williams and I am Director of Regulatory and Legislative Affairs for Environmental Defense Fund. We are an international environmental organization with over 75,000 members in Pennsylvania.

First I want to point out the positive step taken by Governor Wolf on January 8, 2019, when he committed to reduce greenhouse gas emissions across the commonwealth. The federal government's leadership on climate may have stalled, but Pennsylvania has a significant opportunity to lead by setting a declining limit on carbon pollution, and creating the opportunity for flexible, market-based solutions to be deployed to achieve that limit. In this way, Pennsylvania could incentivize the lowest-cost pollution reductions and help ensure that the state has the right framework in place to enhance deployment and utilization of zero-emission energy resources.

Second, and part of his commitment to tackle greenhouse gas emissions, Governor Wolf and the Department of Environmental Protection (DEP) took a critical step to address pollution from existing natural gas sources in Pennsylvania by proposing a draft regulation. Swift and strong action on the ground in Pennsylvania is necessary to provide a backstop for communities that will be impacted by regulatory rollbacks at the federal level.

As the second largest natural gas producer in the nation, the future role of natural gas is vital to Pennsylvania's economic and energy security. Due to market forces and the appeal of cleaner energy generation, power plants are deploying increasing amounts of gas to provide electricity for consumers in Pennsylvania and across the country. It is therefore essential to tackle the front end impacts of natural gas production – methane and VOC leaks and venting – in order for Pennsylvania to maximize the potential benefits of natural gas over other fossil fuels.

Governor Wolf's January 8, 2019, Executive Order, "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance," demonstrates the Administration's desire to ensure improved health, welfare and quality of life for Pennsylvania citizens through environmental protections. In the Executive Order, Governor

Wolf committed to a 26% reduction of net greenhouse gas emissions statewide by 2025 from 2005 levels, and an 80% reduction of net greenhouse gas emissions by 2050 from 2005 levels. Methane is a potent greenhouse gas that is responsible for 25% of the climate change impact we experience today. According to national inventories, the natural gas and oil industry is the largest industrial source of methane emissions. A comprehensive, robust rule that requires operators use modern technologies and practices to reduce emissions from existing oil and gas sources will go a long way towards ensuring the Commonwealth achieves these goals.

While DEP has released a draft existing source rule, as drafted the rule falls short of the elements required to ensure broad reductions in methane and VOCs. The following improvements are necessary in order to meet the Governor's climate goals and provide comprehensive public health protections. Specifically, first, the rule's scope must be expanded to directly regulate methane. Second, the rule should include frequent, at least quarterly comprehensive inspections to detect leaks from all existing wells. The exemption for low-producing wells must be removed. Third, the rule must apply to the same sources covered by the General Permits applicable to new sources, and require the same level of controls for existing as for new sources.

The Commonwealth has over 70,000 existing oil and gas wells. Existing oil and gas sources currently contribute 110,319 tons per year of methane in Pennsylvania, according to reports submitted by operators of oil and gas facilities in Pennsylvania.[1] EDF analysis, based on actual measurements, indicates that actual emissions are at least double these estimates for unconventional natural gas wells and at least 5 times for all natural gas wells.[2]

We estimate that a comprehensive, robust regulation that applies to existing well sites, compressor stations, pigging stations and gas processing plants can reduce methane emissions by 1,023,359 tons from 2018-2020. This assumes that the DEP applies the same control measures to existing sources that it recently finalized in the general permits (GP5 and GP5a) and relies on EDF estimates of existing source emissions. Specifically, we estimate that existing sources will release 1,704,300 tons of methane into the atmosphere between 2018 and 2020. The biggest reductions will come from applying leak detection and repair measures to leaks and abnormal process conditions (637,872 tons), limiting venting from pneumatic controllers (201,372 tons) and limiting venting from centrifugal compressors (126,918 tons).

Measures to reduce emissions from existing sources are highly cost effective. Analysis prepared by ICF International for EDF estimates that off-the-shelf technologies and practices, such as those required under the General Permits, can slash emissions by roughly 40% for a penny per

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[1] PA DEP, *2016 Oil and Gas Air Emissions Report* (*available at* http://www.depgreenport.state.pa.us/powerbiproxy/powerbi/Public/DEP/AQ/PBI/Air_Emissions_OG_Report).
[2] Envt'l Defense Fund, *Penn. Oil and Gas Emissions Data* (*available at* https://www.edf.org/pa-oil-gas/#/reports).

thousand cubic foot of natural gas produced.[3] Also, according to the IEA natural gas companies can reduce between 40% - 50% of their methane emissions at no net-cost.[4]

In addition to being cost effective, controlling methane emissions is simply smart business and results in the reduction of waste (meaning more gas available for sale), better operational efficiency, and reduced risk to Pennsylvania communities – outcomes that all Pennsylvanians can support.

I urge the DEP to take the lead in improving air quality for Pennsylvanians by integrating these recommendations into its existing source rule.

Thank you.

[3] ICF International, *Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries* (March 2014) (available at https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf). c

[4] International Energy Agency, World Energy Outlook 2017 (available at https://webstore.iea.org/world-energy-outlook-2017).

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Senate Democratic Policy Committee Hearing

"Addressing Climate Change in Pennsylvania by Controlling Carbon Emissions"

November 28, 2018

Testimony of Mandy Warner

Good morning, and thank you very much to the Chairs, Senator Boscola and Senator Costa, and other members of the Senate Democratic Policy Committee for the opportunity to speak to you today.

My name is Mandy Warner and I am Senior Manager for Climate & Air Policy at Environmental Defense Fund and am here today representing our approximately 75,000 members across Pennsylvania. EDF is an international environmental advocacy organization with more than one million members nationwide. We are dedicated to finding innovative approaches to solving some of the most difficult environmental challenges. Whenever possible, we aim to collaborate with private-sector partners, state and federal leaders, and other environmental organizations interested in capitalizing on market-based solutions to cost-effectively tackle environmental problems.

I have over 10 years of experience as a policy analyst on climate, energy, and air quality issues. I've been invited today to provide EDF's perspective on addressing climate change in Pennsylvania by controlling carbon emissions, specifically to provide details on the previous plan the Department of Environmental Protection (DEP) was developing to meet the goals of the federal Clean Power Plan.

I would first like to briefly discuss the importance of putting a clear limit on carbon pollution for the Commonwealth, second talk about the Clean Power Plan and DEP's prior engagement, and finally outline the opportunity for Pennsylvania to be a leader on these issues.

Pennsylvania's Needs to Put a Limit on Carbon Pollution

Pennsylvania is the country's third largest emitter of greenhouse gases. While emissions have been falling in the power sector—due in part to market drivers and the transition to low-and-zero emitting resources like renewables and natural gas, they are not falling fast enough. Pennsylvania emitted 89 million metric tons of carbon pollution from the electric power sector in 2016 – this is still more than one-third of the total carbon pollution in the state[1], and the fourth dirtiest power

[1] Note: figure refers to energy-related CO2 emissions.

sector in the country. Pennsylvania is the only state in the northeast without a hard limit on carbon pollution from the power sector- or without a plan to put one in place.

Pennsylvania is already feeling the impacts of climate change. Global temperatures have increased by 2 degrees Fahrenheit since the beginning of the 20th century, leading to an increase in dangerous nor'easters and cyclones; extreme heat especially in urban areas; and coastal flooding as sea levels rise. Increased warming is likely to adversely impact agriculture, the state's number one industry, further deteriorate air quality, and threaten outdoor recreation, including winter sports. Pennsylvania has the opportunity to be a leader in addressing these issues by acting to limit carbon emissions now.

The National Clean Power Plan

In 2015, the U.S. Environmental Protection Agency (EPA) finalized the first-ever national standards to reduce carbon pollution from existing power plants. The Clean Power Plan would deliver a 32 percent reduction in carbon pollution from power plants by 2030 compared to 2005 levels, while also substantially reducing other harmful and often toxic pollution from power plants. As finalized, the Clean Power Plan would prevent 4,500 early deaths and 90,000 childhood asthma attacks each year. The Clean Power Plan set state-specific goals based on three building blocks: 1) improving the efficiency of existing coal plants; 2) dispatching more efficient gas over coal; and 3) increased use of renewables. Energy efficiency was also recognized as a tool that could be used to meet the goals. States had a great degree of flexibility in how to design a program to meet their emissions goal.

Carbon Planning in Pennsylvania

Pennsylvania's Clean Power Plan goal required a 25% reduction in carbon pollution from the power sector by 2030, compared to 2012 levels. The Clean Power Plan was a floor, however, and designed to be a first step towards securing the reductions necessary to put the power sector on track to being nearly completely carbon-free over the next few decades. Such ambitious reductions are what is needed to meet science-based reduction goals across the whole economy.

State planning processes for the Clean Power Plan launched in late 2015, with DEP on track to meet the deadline for a draft or final plan submission to EPA in September 2016. As part of the preparation and information gathering process, DEP undertook a robust public engagement effort to solicit public comments on key issue areas to include in the draft state implementation plan. Specifically, DEP extensively evaluated which program design options would work best for the Commonwealth, including how best to deploy emission reductions under each building block and including energy efficiency investments. DEP focused on how best to develop a flexible compliance program, including evaluating the advantages of implementing an emissions trading system keyed to the lowest cost options. In tandem, DEP evaluated the options for regional collaboration, including program designs which would ensure that as emissions from sources covered by the program decreased, there wouldn't be an *increase* in emissions from sources not covered by the program.

Yet, ultimately, the Clean Power Plan was stayed by the Supreme Court in February 2016. President Trump's EPA is actively working to replace the Clean Power Plan with a policy that will actually increase climate- and health-harming emissions, compared to leaving the Clean Power Plan in place.[2]

Although DEP never issued a draft implementation plan, the insights gained from the planning process can enable thoughtful and timely action from DEP to develop or implement a carbon program. In fact, Virginia is doing exactly that—having prepared for compliance with the Clean Power Plan, state officials realized that there are time-tested strategies available to cut carbon pollution at low cost. When the federal government put the brakes on the Clean Power Plan, Virginia's Department of Environmental Quality continued to move forward with the development of a state pollution reduction strategy. Virginia's approach acknowledges the real impacts already being felt by residents because of a changing climate and the judiciousness of taking swift action.

In comments filed with EPA last month, DEP noted that as of 2016, "Pennsylvania has already exceeded its 2030 CPP goal… through a combination of market-driven techniques like fuel switching and renewable energy standards while maintaining its status as a net energy exporter."[3] More ambitious reductions are necessary and eminently achievable, but this rapid progress in meeting the CPP goal in Pennsylvania indicates the feasibility and cost-effectiveness of further reducing carbon emissions in Pennsylvania and in states across the country, who have seen similar declines in power sector emissions. Recent analyses from the US government, technical experts, and others note, however, that power sector emissions could plateau and even begin to increase in the near future if nothing is done. This potential increase in near-term emissions presents a significant concern for our nation's ability to achieve our climate goals if no firm limit is placed on carbon.[4]

Pennsylvania's Opportunity for Leadership

The federal government's leadership on climate may have stalled, but Pennsylvania has a significant opportunity to lead by setting a declining limit on carbon pollution, and creating the opportunity for flexible, market-based solutions to be deployed to achieve the limit. In this way,

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[2] EDF Blog, "The Trump Administration's Clean Power Plan Replacement – for many states, worse than doing nothing," September 14, 2018, available at: http://blogs.edf.org/climate411/2018/09/14/the-trump-administrations-clean-power-plan-replacement-for-many-states-worse-than-doing-nothing/?_ga=2.52240233.1798795442.1543248419-1688373484.1539633473

[3] Comments of Pennsylvania DEP, "Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guideline Implementing Regulations; Revisions to New Source Review Program," October 31, 2018. Available at: http://files.dep.state.pa.us/AboutDEP/Testimony/PADEP%20Comment_ACE%20Rule_EPA-HQ-OAR-2017-0355.pdf

[4] See: Rhodium Group, "Taking Stock 2018," June 28, 2018, available at: https://rhg.com/research/taking-stock-2018/; US Energy Information Administration, *Annual Energy Outlook 2018*, February 6, 2018, available at: https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf; and Union of Concerned Scientists, *The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions*, November 2018, available at: https://www.ucsusa.org/sites/default/files/attach/2018/11/Nuclear-Power-Dilemma-full-report.pdf

Pennsylvania will incentivize the lowest-cost pollution reductions and help ensure that the state has the right framework in place to enhance deployment and utilization of zero-emission energy resources. Pennsylvania and the power sector as a whole have made progress reducing emissions rapidly and cost-effectively, the result of many factors including the planning done for complying with the Clean Power Plan, the plummeting cost of renewable energy, and other state and federal policies. However, deeper reductions are necessary to meet our climate objectives.

In order to achieve these objectives, Pennsylvania needs to ensure that there is a plan in place to accelerate the decarbonization underway in the power sector – which means both preventing any *increases* in carbon emissions from the power sector as well transitioning carbon-intensive fossil generation to zero-emission renewable energy, and finally leverage that cleaner electricity to help decarbonize the rest of the state's economy. A declining limit on carbon pollution for the power sector will allow Pennsylvania to deploy technology solutions that work best for the Commonwealth.

Carbon pricing policies are in place or expanding in much of the PJM region. States like Virginia,[5] New Jersey,[6] Illinois,[7] and more are looking to move forward on carbon. Pennsylvania must not sit on the sidelines while other states make significant and prudent investments in clean energy. By acting to limit carbon emissions, Pennsylvania will maintain competitiveness within the regional electricity space while preventing competing interests to allow the state to become a bastion for carbon intensive generation resources. It is also worth noting that PJM examined regional and subregional carbon pricing frameworks in a report issued last year and stated that "PJM believes that a coordinated carbon policy could be advanced through the PJM markets..."[8] The report also noted that issues such as emissions leakage between states can be minimized through the frameworks they described.

To conclude my remarks today, EDF commends the committee for hosting this important discussion on addressing climate change, and respectfully suggests that Pennsylvania should set a binding limit on carbon pollution. By adopting a technology-neutral and outcomes-oriented approach, Pennsylvania can secure the emission reductions necessary at the lowest possible cost and continue to meet the energy needs of the state, securing its role as a zero-carbon net energy exporter. Placing a firm limit on carbon pollution – and then letting that carbon pollution "limit" drive a price in the energy market can help ensure the most cost-effective deployment of zero-emission resources and energy efficiency.

Thank you again for the opportunity to testify today.

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[5] Virginia Governor Terry McAuliffe, *Executive Order 57*, see: https://www.naturalresources.virginia.gov/media/governorvirginiagov/governor-of-virginia/pdf/eo/eo-57-development-of-carbon-reduction-strategies-for-electric-power-generation-facilities.pdf

[6] New Jersey Governor Philip Murphy, letter on intent to rejoin RGGI, available at: https://www.state.nj.us/dep/aqes/docs/letter-to-rggi-governors20180222.pdf

[7] Illinois Governor-elect J.B. Pritzker has pledged to join the U.S. Climate Alliance. See: https://www.jbpritzker.com/environment/

[8] PJM, *Advancing Zero Emissions Objectives through PJM's Energy Markets: A Review of Carbon-Pricing Frameworks*, August 23, 2017.

Appendices

A. Comments of Environmental Defense Fund on "Pennsylvania's Path to Compliance with EPA's Final Rule for Carbon Pollution Emissions Guidelines for Existing Sources: EGUs (Clean Power Plan)"
B. Pennsylvania Department of Environmental Protection Presentation on the Clean Power Plan
C. Testimony of Rama Zakaria, Environmental Defense Fund, before the Pennsylvania Nuclear Energy Caucus