Petition of PECO Energy Company-Gas for a Finding of Necessity Pursuant to 53 P.S Section 10619 That the Situation of Two Buildings Associated with a Gas Reliability Station in Marple Township, Delaware County Is Reasonably Necessary for the Convenience and Welfare of the Public – On Remand	Docket No.: P-2021-3024328
Call-In Telephonic Further Hearings	

Pages 2172 - 2359

Judge's Chambers

State Office Building

801 Market Street

Philadelphia, PA

Wednesday, November 15, 2023

Commencing at 10:00 a.m.

INDEX TO EXHIBITS

Docket No. P-2021-3024328

Hearing Date: November 17, 2023

NUMBER	FOR IDENTIFICATION	IN EVIDENCE
Marple Township, Ted Uhlman, and Julie Baker Remand Statement 2	2250	2274
Najjar Remand Direct Testimony		
Marple Township's Exhibit RN-1	2251	2274

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

PETITION OF PECO ENERGY COMPANY FOR A FINDING OF NECESSITY

PURSUANT TO 53 P.S. § 10619

Docket No. P-2021-3024328

REMAND DIRECT TESTIMONY

WITNESS: DR. RAYMOND G. NAJJAR, JR.

SUBJECT: PROVIDE EXPERT TESTIMONY REGARDING THE POTENTIAL ENVIRONMENTAL CONSEQUENCES ASSOCIATED WITH PECO'S PROPOSED GAS RELIABILITY STATION TO BE LOCATED AT 2090 SPROUL ROAD, MARPLE TOWNSHP, PA.

DATED: September 22, 2023

BEFORE THE COMMONWEALTH OF PENNSYLVANIA
PENNSYLVANIA PUBLIC UTILITY COMMISSION

Petition of PECO Energy Company for a Finding of Necessity Pursuant to 53 P.S. § 10619 that the Situation of Two Buildings Associated with a Gas Reliability Station in Marple Township, Delaware County Is Reasonably Necessary for the Convenience and Welfare of the Public	))))))	Docket No. P-2021-3024328 (On Remand)

Direct Testimony of

Dr. Raymond G. Najjar, Jr.

September 14, 2023

1. Q. What are your name, address, and occupation?

A. My name is Raymond G. Najjar, Jr. I live at 938 South Sparks Street, State College, Centre County, Pennsylvania. I am employed by The Pennsylvania State University (Penn State), where I am a Professor of Oceanography in the Department of Meteorology and Atmospheric Science, with a joint appointment with the Department of Geosciences.

2. Q. What is the purpose of your testimony, as you understand it?

A. I am testifying on behalf of Ted Uhlman and Julie Baker in a hearing on remand before the Pennsylvania Public Utility Commission ("PUC") on remand for consideration of the environmental impacts of a station in Marple Township as part of a project by PECO to increase the local distribution of natural gas ("Project"), which PECO contends is to promote reliability. My testimony is intended to provide my expert opinions on (1) how emissions from combustion of natural gas and other fossil fuels drive climate change, (2) resources protected under Article I, § 27 of the Pennsylvania Constitution, (3) why Pennsylvania and the rest of the world cannot expand infrastructure that will lead to increased combustion of fossil fuels without increasing damage to Section 27 resources, (4) how climate change already occurring has reduced demand for natural gas for heating over the winter and will further reduce demand in the future, and (5) how the Project will not be needed to meet the needs of existing customers but will only increase fossil fuel combustion and further damage Section 27 resources. A summary of my opinions, which are reached to a reasonable degree of scientific certainty, are expressed below in my report ("Report") which is attached to this testimony as Uhlman-Snyder Remand Exhibit 1.

3. Q. What are your qualifications to testify on the causes and impacts of climate change, the effect of climate change and how that will affect demand for heating, mitigation that will be required to avoid the worst effects of climate change, and

how emissions caused by the PECO project will contribute to climate change, if approved?

A. I graduated from the Cooper Union for the Advancement of Art & Science in 1985 with a degree in Mechanical Engineering, where I studied numerous subjects that laid the foundation of my work in climate science, including fluid mechanics, thermodynamics, and transport phenomena. In 1987, I earned a Masters in Geophysical Fluid Dynamics from Princeton University. In 1990, I earned my Ph.D. in Atmosphere and Ocean Science from Princeton University. I was a post-doctoral scholar at the National Center for Atmospheric Research from 1990 to 1993. My early research focused on large-scale, open-ocean biogeochemistry, particularly the cycling of nutrients (nitrogen, phosphorus, and silicon), oxygen, and carbon. A few years after arriving at Penn State in 1993, I became interested in coastal issues, such as eutrophication, hypoxia, and sea-level rise. I worked on numerous regional climate impact assessments, including one that was part of the first National Climate Assessment. I am mainly a data analyst, but I also use numerical models and remote sensing. I have conducted field studies in the Sargasso Sea and coastal waters of Antarctica, the Eastern United States, and Florida. I have received funding for my research from the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the National Science Foundation, the Department of Energy, the Pennsylvania Department of Environmental Protection, and Pennsylvania Sea Grant.

At Penn State, I teach undergraduate and graduate courses on meteorology, atmospheric science, fluid dynamics, physical oceanography, marine biogeochemistry, and scientific communication. The material in these courses lays the foundation for climate science and many of the courses directly discuss global warming. For years now, my work has focused on the science

of climate change. I conduct research on climate change, publish papers on it, give regular talks to public and professional audiences about it, and direct two educational programs at Penn State about it (the Dual Title Ph.D. Program in Climate Science and the Research Experiences for Undergraduates Summer Climate Science Program). My research has been published in peer-reviewed scientific journals, including *Nature*, *Nature Climate Change, the Proceedings of the National Academy of Sciences*, the *Journal of Climate*, *Climatic Change*, and *Climate Research*. I have been an author of numerous regional climate impact assessments, including three reports the Pennsylvania Department of Environmental Protection has produced in compliance with the Pennsylvania Climate Change Act (Act 70 of 2008). Other climate impact assessments and climate-related reports I have contributed to include the First U.S. National Climate Assessment, the Second State of the Carbon Cycle Report (a U.S. Global Climate Change Research Program Sustained Assessment Reports), and reports analyzing the Delaware Bay, Chesapeake Bay, and their watersheds, which take up a large part of the Commonwealth's area.

The Commonwealth Court accepted my qualifications to testify as an expert on climate change causes, impacts and mitigation in the litigation challenged the Regional Greenhouse Gas regulation.

For more detail about my work, I have attached my curriculum vitae.

4. Q. What have you reviewed to prepare for your testimony regarding the Project?

A. I have reviewed (1) the Administrative Law Judge's Initial Decision, (2) the Final Decision of the PUC, (3) the Opinion of the Commonwealth Court, and (4) portions of the PUC evidentiary hearings transcript, including the testimony of Ryan Lewis regarding the basis for

PECO's determination that the Project was necessary and the fact that he failed to consider climate change in that determination.

5. Q. What is the current scientific understanding of climate change and its causes?

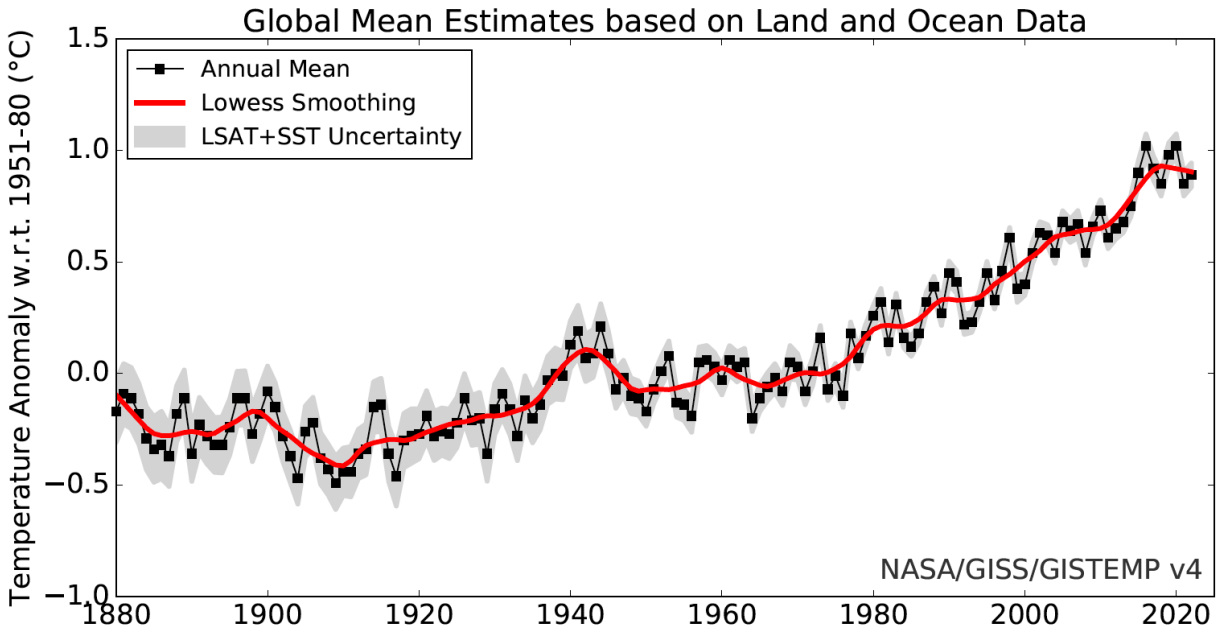


Fig. 1. Global mean surface-air temperature departure from the 1951–1980 baseline, including annual averages (black squares) and their uncertainty with 95% confidence (gray shading), and a smoothed analysis (red line). Source: NASA Goddard Institute for Space Studies.

A. When we refer to "climate change," or more specifically "anthropogenic climate change," we are referring to the long-term changes in the atmosphere and other components of the climate system (e.g., the ocean and cryosphere) due to increased concentrations of greenhouse gases in the atmosphere. The most prominent of these changes is the increase in average temperatures found in most places across the globe—that is to say: global warming. Evidence for global warming is presented in Figure 1 in my Report, which shows the increase in Earth's average surface air temperature from 1880 to 2022 as estimated by NASA. Warming has been particularly

rapid over the last 50 years, during which the mean temperature increased by more than 1 °C (1.8 °F). The last nine years are the hottest nine years on record. The same source of climate data (NASA) also shows 2023 thus far to be particularly warm, with June being the hottest month ever recorded, well above the previous record. Additional evidence for global warming comes from increases in humidity, ocean temperature, and sea level, and decreases in snow cover, glacier extent, and sea ice extent, and many more metrics.

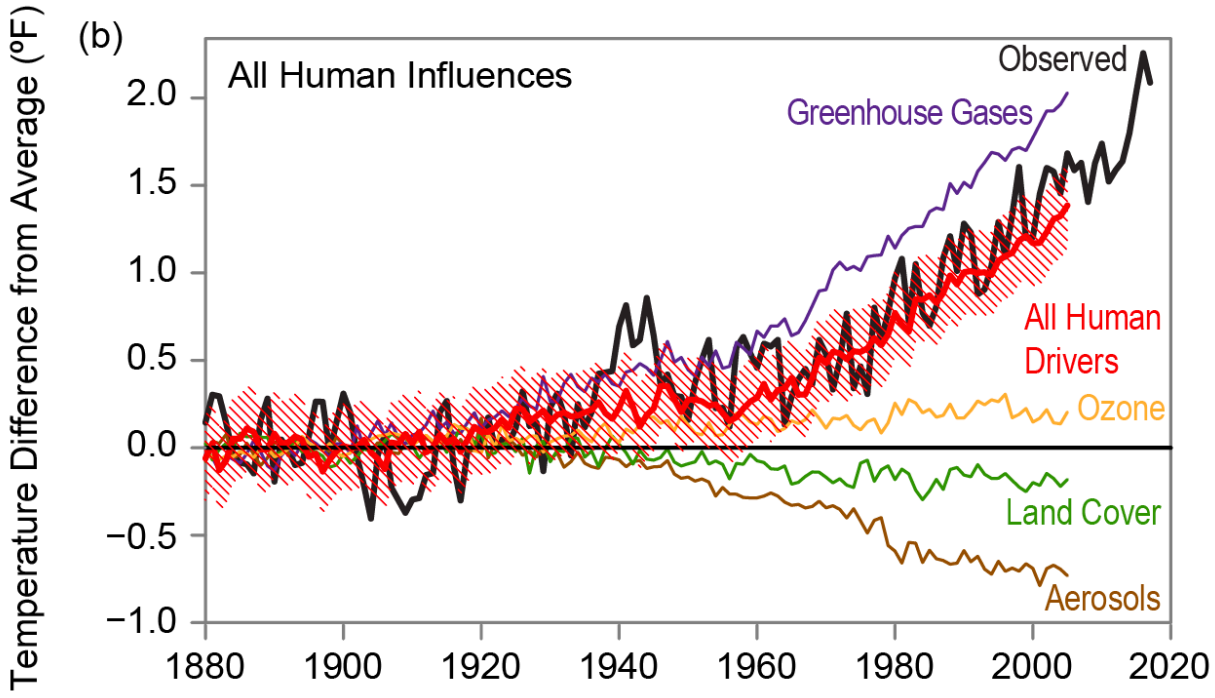


Fig. 2. Simulated (colored lines) and observed (black line) climate from the late 19th century to the early 21st century. The simulations show the individual impacts of human drivers as well as the combined impact of these drivers. Source: Fourth National Climate Assessment, Hayhoe et al. (2018).

The cause of this steady upward march in temperature is well understood. Sources of natural variations in temperature, such as changes in the intensity of sunlight, Earth's orbital dynamics, and volcanic activity, do not explain the warming. While such changes do cause fluctuations in temperature, those fluctuations are minor and result in very weak long-term

temperature trends. Human activities, on the other hand, explain the observed temperature changes extremely well. As seen in Figure 2 from my Report, temperature changes modeled from emissions of greenhouse gases from human activities track observed global temperatures changes, and in fact are dampened somewhat by global cooling effects from atmospheric aerosol pollution and changes in land cover. Greenhouse gases warm the climate by absorbing infrared radiation that is emitted by the surface of the Earth. These gases effectively trap radiation that would otherwise escape from the Earth's atmosphere to space.

The science of global warming has long been settled. The greenhouse effect was discovered in the 1820s by Joseph Fourier and the connection between climate and fossil fuel burning was made by Svante Arrhenius, who won the Nobel Prize for Chemistry in 1903 for this discovery. No serious climate scientist today in 2023 disputes that emissions from burning fossil fuels is the primary driver of climate change over the past century. The questions in the field of climate science today focus on very specific issues, such as the impact of global warming on the frequency and intensity of hurricanes and tornados. Another important unknown surrounds tipping points in the climate system, such as rapid collapse of ice sheets and melting of the tundra that would lead to release of massive quantities of methane, which would further accelerate global warming.

6. Q. What are the effects of climate change and how will these impact Pennsylvania and the resources that are subject to the Pennsylvania Environmental Rights Amendment?

A. The effects of climate change on human society and on the ecology of the planet are overwhelmingly negative and, in some aspects, extremely severe. It is no exaggeration to call global warming the most pressing problem humanity faces today. Nor will this problem go away any time soon. Even if all nations stopped burning fossil fuels and otherwise emitting greenhouse

gases today, we would continue to see the climatic effects of the accumulated greenhouse gases in the atmosphere for many decades to come. However, any reductions we do make today will pay dividends in the form of a stabler and less extreme climate in the coming years.

The global and regional impacts of climate change are already staggering. For example, in 2018, 134 billion potential work-hours were lost globally due to extreme heat, a 34% increase above the 2000 baseline. Ecosystems we depend on are being severely compromised through the bleaching of coral reefs and the raging of forest fires. The forest fires in the western U.S. in the summer and fall of 2020 were so bad that even here in Pennsylvania, our skies were darkened by the soot that was generated. Even much more extreme were the impacts of Canadian wildfires this year, which severely degraded air quality in many portions of the U.S., including Pennsylvania, forcing millions of people indoors.

Over the past 100 years, Pennsylvania has warmed by about 2 °F, in accordance with expectations from rising greenhouse gases, and the warming rate is accelerating. Throughout the Mid-Atlantic region, the impacts of warming on ecosystems are being felt in multiple ways: plants are blooming and leafing out earlier, native bees are arriving earlier, and birds are getting smaller. More threateningly, the larval peak of ticks is arriving earlier, very likely contributing to the explosion of Lyme disease throughout the Northeast U.S., including Pennsylvania. Warming streams threaten—and may eventually result in the end of—both native and stocked trout and other fishing. Many of these impacts of climate change are having increasingly negative economic impacts on Pennsylvanians.

Warming in Pennsylvania has been particularly significant in the winter, with temperature increases since 1970 exceeding 3 °F in all of the Pennsylvania's counties and reaching as high as 5 °F in Philadelphia, as shown in Figure 3 from my Report. Winter warming has led to more of

our precipitation falling as rain instead of snow and fewer days per year with snow on the ground. These declines in snow are fundamentally changing the character of Pennsylvania, threatening winter recreation industries, and affecting some of wildlife, like the snowshoe hare, which is contracting in its range due to a loss of snowpack. Warmer winters are also more likely allowing the wooly adelgid, an invasive insect, to attack our state tree more aggressively, the Eastern Hemlock.

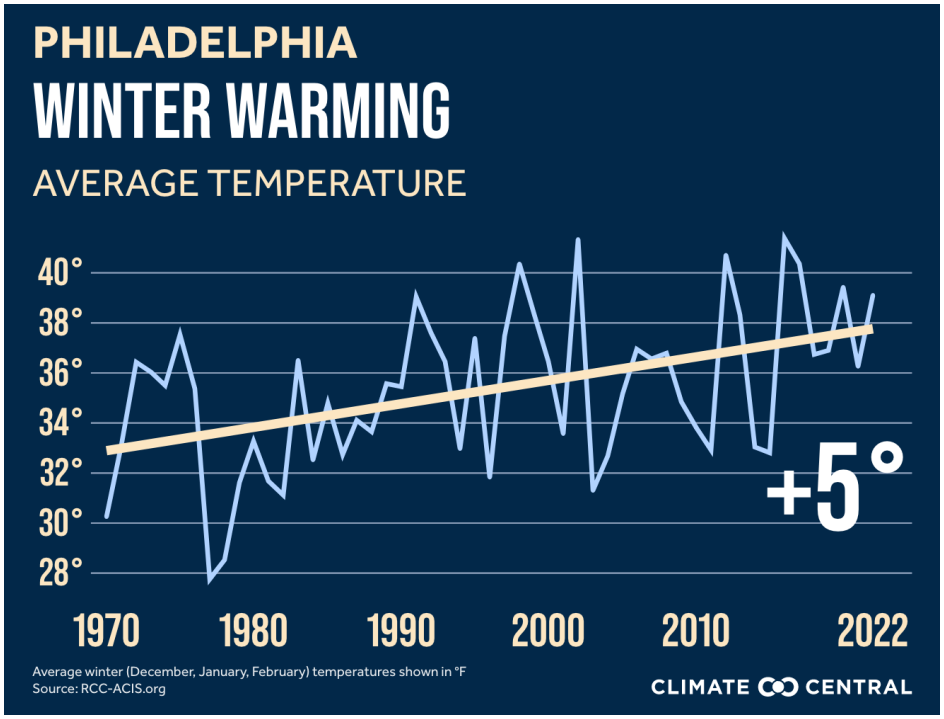


Fig. 3. Average winter temperature (°F) in Philadelphia from 1970 to 2022 (blue line) and the corresponding linear trend (yellow line), which is used to determine an increase in 5 °F over this period. Source: Climate Central.

Much more dramatic warming is expected in the coming decades. If greenhouse gas emissions continue to rise as they have been rising, the summer climate of Pennsylvania will come to resemble that of the southeastern U.S. by the middle of the 21st Century, as illustrated in Figure 4 of my Report, which shows projected future summer temperatures in Pennsylvania cities as compared to today's summer temperatures in southeastern U.S. cities.

Fig. 4. Summer climate projections for Pennsylvania based on the Pennsylvania Climate Impacts Assessment Report, comparing the summer climate of a historical period (1971–2000) to that of mid-century (2041–2070) using a "moving cities analogue" (Shortle et al., 2015). For example, Harrisburg, Pennsylvania has historically had an average summer temperature of 75.9 °F. But if current emissions trends continue, Harrisburg's average summer temperature for the future period will increase to 81.3 °F, which is historically Birmingham, Alabama's average summer temperature.

Another notable impact of warming is on the quality precipitation, which is getting more intense with time. Specifically, there has been a 71% increase in the top one percent of rainiest days from 1958 to 2012, as shown in Figure 5 from my Report. Furthermore, these heavy downpours, which overwhelm the stormwater and sewer systems infrastructure across the Commonwealth, are expected to continue to increase, as shown in Figure 6 from my Report. The memorable pictures of the massive floods in downtown Philadelphia from Hurricane Ida in 2022 splashed across the news are a glimpse of what may come more often should greenhouse gas emissions trends continue unchecked.

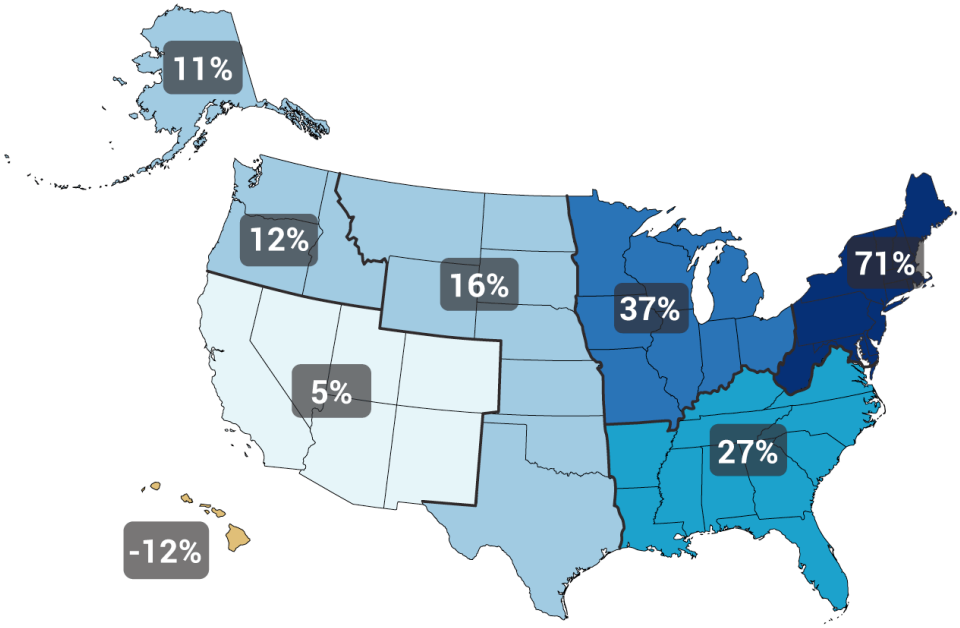


Fig. 5. Change in the top 1% of rainiest days in the U.S. from 1958 to 2022. Source: Walsh et al. (2014).

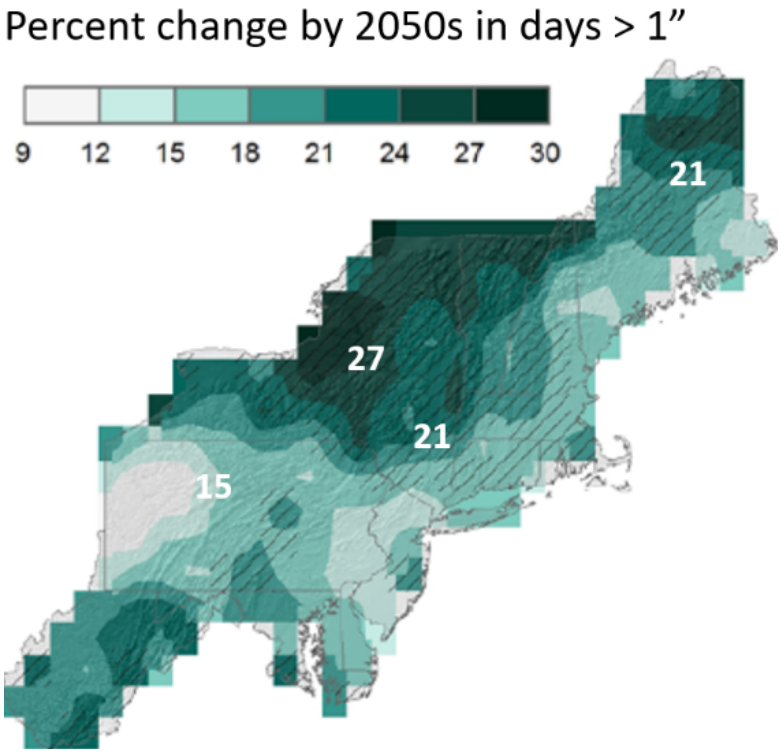


Fig. 6. Projected change in the Northeast U.S. of heavy downpours, as measured by the number of days per year with precipitation exceeding 1 inch, by the 2050s. Source: Kunkel et al. (2013).

In the Northeast United States, including Pennsylvania, climate models predict that precipitation will increase, mainly in the winter, though summers are expected to be drier, as shown in Figure 7 from my Report. The combined effect of lower precipitation and higher temperatures during the summer means that soils will most likely be much drier in the future, which will require changes in agricultural practices, including crop choice and irrigation.

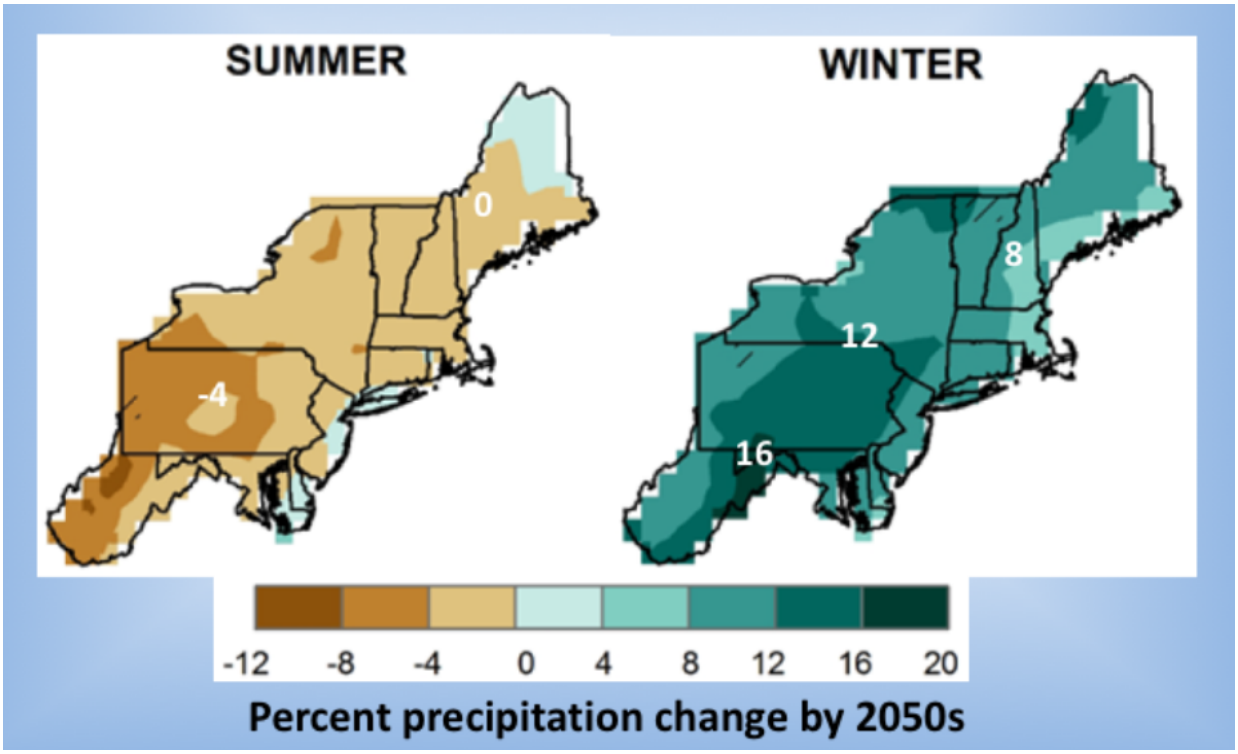


Fig. 7. Projections of summer and winter precipitation change in the Northeast U.S. by the 2050s. Source: Kunkel et al. (2013).

One of the other primary effects of rising temperatures is an increase in the average elevation of the oceans. Figure 8 of my Report shows the measured rise in sea levels averaged over the Earth from 1900 to the present. Sea levels have not only risen but accelerated, with the quickest rise being since roughly 1990, at 3.6 millimeters increase per year, 6 times the rate from the first three decades of the 20th century. Rates of sea-level rise vary over space as well, with quite high rates in Philadelphia, 4.7 millimeters per year since 1991. Sea levels rise not only because higher

temperatures melt ice, such as in Greenland and Antarctica, but also because warming causes water to expand. As with the rise in atmospheric temperatures, the amount of sea-level rise is directly related to the amount of greenhouse gases that are emitted.

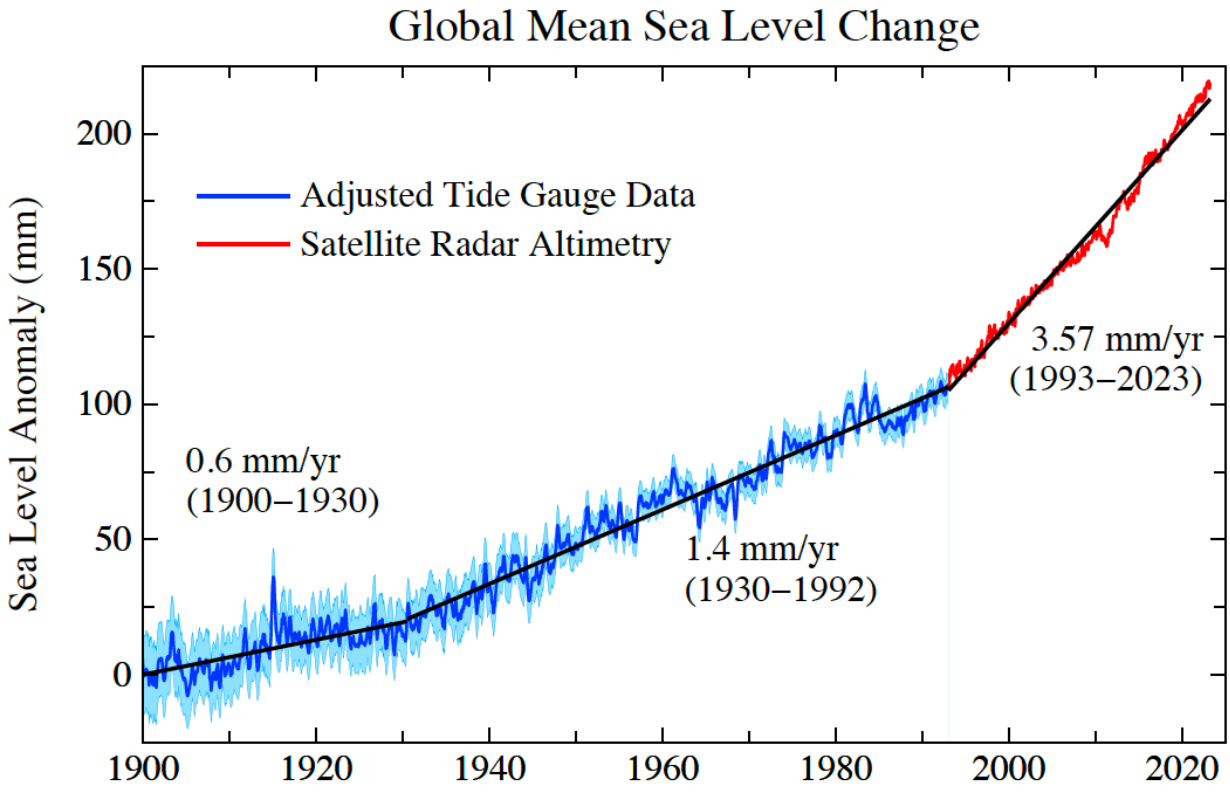


Fig. 8. Globally averaged sea level from 1900 to the present day. Source: Columbia University's Earth Institute.

Sea-level rise has caused nuisance flooding to increase dramatically in many cities throughout the U.S., including Philadelphia, as shown in Figure 9 from my Report. Sea-level rise has also caused the salinity of the Delaware Bay downstream to increase, which is a cause for concern because if salt intrusion extends further upstream, it will threaten intakes for drinking water and industrial use in the greater metropolitan area of Philadelphia.

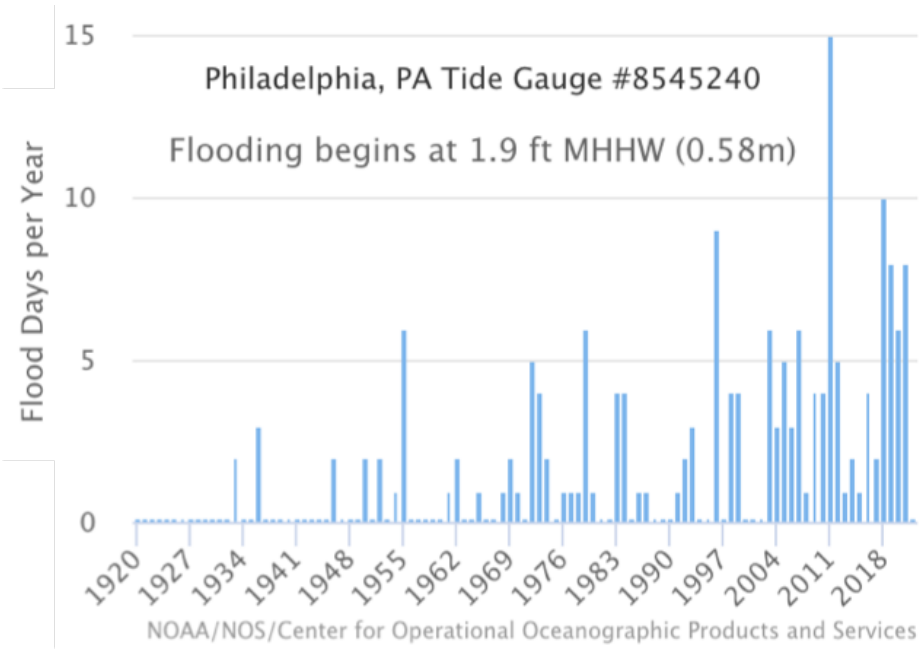


Fig. 9. The number of flood days per year in Philadelphia, as measured by water levels exceeding 1.9 feet about mean high water (MHHW), which is the average of the higher of the two high tides per day. Source: NOAA.

7. Q. What is your opinion regarding how climate change will affect demand from PECO's existing customers for natural gas during peak winter months?

A. Climate change will reduce demand for natural gas during peak winter months. Indeed, given the rapid winter warming of southeastern Pennsylvania over the last 50 years, noted earlier in my response to Question 6, climate change must already be reducing demand. The fact that demand has increased is due to other factors, such as population growth.

Heating fuel demand increases as the number heating degree days (HDDs) increase. HDDs for a winter season are calculated by first determining the number of degrees that the average temperature for a winter day is below 65 °F. For example, if the average temperature for a day is 55 °F, then the HDDs for that day is equal to 10. The HDD is zero for any day in which the daily average temperature is above 65 °F. HDDs for a whole winter is simply the sum of HDDs for individual winter days. The Delaware Valley Regional Planning Commission hired the

consulting firm ICF to conduct a climate impacts analysis for several counties in southeastern Pennsylvania. The results of their HDD analysis for Delaware County are shown in Figure 10 of my Report. Compared to the baseline HDDs given by the 1961–1999 period, average HDDs for the 2020–2039 period are projected to decline by 10%, regardless of greenhouse gas emissions scenario. HDDs are projected to continue decline throughout the 21st century, with greater declines for higher emissions scenarios, and as much as a 35% decrease by the end of the century.

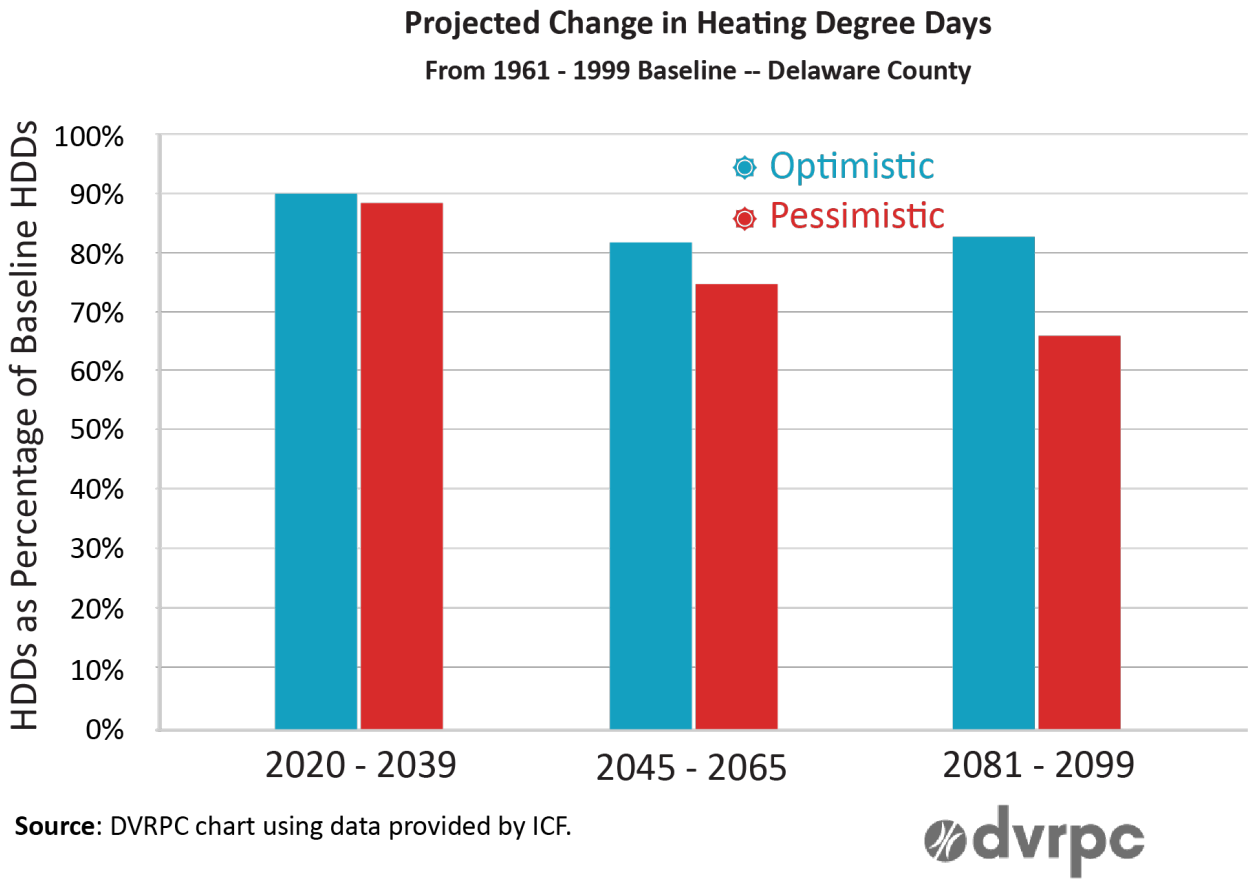


Fig. 10. Projected heating degree days (HDDs) as a percentage of baseline HDDs (1961–1999 period) for Delaware County. Two greenhouse gas emissions scenarios are shown: an optimistic scenario (RCP4.5) and a pessimistic scenario (RCP8.5); RCP = representative concentration pathway and 4.5 and 8.5 refer to the enhanced greenhouse gas heating in watts per meter squared. Source: Delaware Valley Regional Planning Commission.

In contrast, the same analysis by ICF concluded that cooling degree days (CDDs), defined in the same way as HDDs but considering temperatures above 65 °F, are projected to dramatically increase in the future. Thus, installing energy efficient heat pumps to meet both heating and cooling requirements can save consumers money, while reducing greenhouse gas emissions.

8. Q. Could you please describe for the Court the scientific consensus, if any, regarding the reductions in greenhouse gas emissions that will be necessary?

A. Although climate change is already having profound adverse effects on Pennsylvania's environment, those effects can be expected to increase and, without reductions in emissions of carbon dioxide and other greenhouse gases, could reach disastrous levels. The nations of the world, including the United States, have entered into the United Nations Framework Convention on Climate Change (UNFCCC), whose objective is to limit greenhouse gas emissions to prevent "dangerous anthropogenic interference with the climate system." The nations party to the UNFCCC and the scientific community agree that this will require limiting warming to 1.5 to 2 °C above historic levels. The scientific community, in a series of consensus studies, agrees that this will require the world to reduce greenhouse gas emissions by 50% from 2005 levels by 2030 and to achieve greenhouse emissions neutrality by 2050. President Biden has adopted these science-based goals, which are reflected in the Federal Sustainability Plan.

The Intergovernmental Panel on Climate Change and other scientific bodies have concluded that these emissions reductions will require the replacement of fossil fuel combustion with energy sources that do not generate greenhouse gases, increases in energy efficiency, and measures to capture carbon dioxide from the atmosphere and sequester it (e.g., belowground). The U.S. Environmental Protection Agency (EPA) has found that where power plants cannot

generate electricity from non-fossil sources (e.g., nuclear, wind, solar, hydroelectric, biomass and other renewables), fossil-fired power plants can and must capture and sequester carbon dioxide—and the EPA has proposed a rule requiring this. Please see *New Source Performance Standards for Greenhouse Gas Emissions From New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions From Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule*, 88 Fed. Reg. 33240 (May 23, 2023).

Because electricity can be decarbonized, achieving the reductions necessary to avoid the worst impacts of climate disruption will require (1) discontinuing fossil fuel use in situations where carbon dioxide emissions cannot be captured by pollution control and (2) using electricity to provide the power for those situations. For the latter, this means that appliances that use natural gas and oil in buildings for heating, cooling, cooking, and hot water be replaced with electric appliances, such as energy-efficient heat pumps, induction cook tops, and other electrical appliances whose use has been encouraged by Congress in the Inflation Reduction Act. Decarbonizing also makes sense in a warming climate because of the current and projected increases in summer cooling demand and decreases in winter heating demand. Because cooling is generally provided by electricity and heating by fossil fuels, we should expect increased demand for energy that can be decarbonized (like electricity) and a decreasing demand for energy that cannot (like natural gas).

The need to reduce emissions by 50% by 2030 and to achieve emissions neutrality by 2050 makes it imperative that we not build new infrastructure to expand use of fossil fuels in situations where greenhouse gas emissions cannot be captured and sequestered.

9. Q. Is the Project the type of infrastructure that will result in increases of greenhouse gas emissions exceeding those that will allow Pennsylvania, the United States and the World to achieve the emissions reductions that will be necessary, as you have discussed in your previous testimony, and, if so, why?

A. Yes. Based on the Findings of Fact, the primary purpose of the proposed Natural Gas Reliability Station is to support expanded use of natural gas based on its "calculated design day demand requirements" (FF 15). The Project is needed to address winter deficits (FF18-20) and "customer and usage growth in Delaware County" (FF24). PECO based this growth on a "linear trend analysis," which extrapolates past growth in customer count and usage over the next ten years (FF25-28). PECO did not take account of climate change in its modeling (N.T. 1212-1213, 0589A-0590A). If climate change is properly considered, as required in an analysis consistent with Article I, § 27, it can readily be determined that peak winter demand from existing customers will be reduced, such that the real intent of the project is to increase distribution and use of natural gas for residential and commercial buildings, increase greenhouse gas emissions and lock those increases in for decades to come.

If infrastructure is built to serve new homes and businesses that are built to use natural gas rather than electricity, there will be two impacts: (1) fossil fuel combustion will increase where emissions cannot be captured and (2) emissions will be locked in for decades to come, with new building and new distribution gas lines. Such impacts are inconsistent with the need to reduce those emissions and achieve emissions neutrality by 2050.

The expanded infrastructure can also be expected to result in leaks of methane, a greenhouse gas that is far more potent than carbon dioxide. A review of the literature on methane leaks in U.S. natural gas distribution reveals that leaks from distribution system release the

greenhouse gas equivalent of 2% of on-road emissions in the U.S. From a monetary perspective, it would make sense to repair such leaks because the climate damages of the released methane are about 5 times the repair costs. However, from the perspective of distribution companies, it is not worth it to repair the leaks because the cost of the lost methane to them is relatively small and simply passed on to customers.

10. Q. In your opinion, does it matter that the emissions from the Project will be small in comparison to overall world emissions?

A. No, because in order for the necessary reductions in world emissions to take place, reductions must come from all parties that currently contribute to emissions. Furthermore, every ton of carbon dioxide emitted leads to damage, including loss of human life. By one estimate, every 500 metric tons of carbon dioxide emitted now leads to a human death by 2100. For reference, Pennsylvania's CO_2-equivalent emissions in 2019 (the most recent estimate available) amounted to 266 million metric tons, which is the equivalent of about 50,000 deaths worldwide by 2100.

According to the Second State of the Carbon Cycle Report (SOCCR2, which I was an editor of), human-driven CO_2 emissions are expected to continue to drive changes in climate in the coming decades and centuries. In fact, the first key finding of the SOCCR2 report was that emissions from fossil fuel combustion in the North American energy sector are a source of carbon to the atmosphere. Reducing the current output of carbon and greenhouse gas emissions is directly tied to limiting global surface temperature change to levels that will limit these many harms, as was described in the recent 2022 report of the Intergovernmental Panel on Climate Change. While no one individual state or country policy will singlehandedly solve the problem

of climate change and rising temperatures, it is critical that these individual steps be taken in order to contribute to solving the problem collectively.

11. Q. Will you please summarize your conclusions and opinions, to a reasonable degree of scientific certainty?

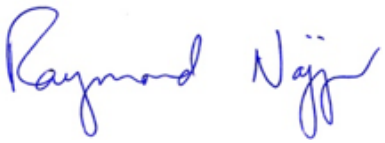
A. Humans are massively and rapidly transforming the climate. The overwhelming majority of the impacts are negative and will get worse. For example, coral reefs, one of the most important and wondrous ecosystems on Earth, are poised for permanent demise as a result of overheating and acidification. The local ecology is shifting and is likewise poised for permanent and irreversible harm and devastation. If we do not act quickly and aggressively to reduce greenhouse gas emissions or remove carbon dioxide from the atmosphere, we will be leaving a planet to our children and grandchildren that is a shadow of its former self. While our knowledge of the climate system is not perfect—and never will be—we know enough to act. Fossil fuels have served society very well but they have outlived their usefulness as our sole source of energy, and they cannot be allowed to freely externalize their costs onto society any longer.

It is my opinion that limiting infrastructure that will increase use of fossil fuels, such as the Project, is critical to mitigating the effects of climate change, which is necessary to protect the public interest and the health and welfare of Pennsylvanians and their water, air, and environment and other resources protected under Article I, § 27 of the Pennsylvania Constitution.

VERIFICATION

I, Dr. Raymond G. Najjar, Jr, hereby verify that the facts contained in the foregoing testimony are true and accurate to the best of my knowledge and that I am duly authorized to make this verification, and that I expect to be able to prove the same at any hearing held in this matter.

Dated: September 14, 2023



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Biographical Sketch of Raymond G. Najjar
(updated March 27, 2023)

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1. Education and professional experience

Ph. D. Princeton University, Atmospheric and Oceanic Sciences, 1990
M. A. Princeton University, Geophysical Fluid Dynamics, 1987
B. E. The Cooper Union for the Advancement of Art and Science, Mechanical Engineering, 1985

2011–present. Professor, Department of Meteorology and Atmospheric Science, The Pennsylvania State University
2000–2011. Associate Professor, Department of Meteorology, The Pennsylvania State University
June–December 2001. Guest Investigator, Woods Hole Oceanographic Institution.
1993–2000. Assistant Professor, Department of Meteorology, The Pennsylvania State University
1990–1993. Post-Doctoral Fellow, Advanced Study Program and Climate System Modeling Program, National Center for Atmospheric Research
July 1990. Teaching Assistant, Department of Oceanography, University of Washington
1989–1990. Research Associate, Program in Atmospheric and Oceanic Sciences, Princeton University
1985–1990. Graduate Research Assistant and NASA Graduate Student Researcher, Program in Atmospheric and Oceanic Sciences, Princeton University

2. Teaching

Courses taught (since 2001)

Spring 2023: Meteo 451 (Physical Oceanography)
Fall 2022: Meteo 520 (Geophysical Fluid Dynamics)
Spring 2022: Meteo 300 (Fundamentals of Atmospheric Science) and Geosc 410 (Marine Biogeochemistry)
Fall 2021: Meteo 520 (Geophysical Fluid Dynamics)
Spring 2021: Meteo 551 (Physical Oceanography)
Spring 2021: Meteo 296 (Independent Study in Physical Oceanography for Jason Epstein)
Fall 2020: Meteo 300 (Fundamentals of Atmospheric Science)
Fall 2020: Meteo 496 (Independent Study in Physical Oceanography)
Spring 2020: Meteo 300 (Fundamentals of Atmospheric Science)
Fall 2019: Meteo 551 (Physical Oceanography)
Spring 2019: Meteo 451 (Physical Oceanography) and Geosc 410 (Marine Biogeochemistry)

Fall 2018: Meteo 300 (Fundamentals of Atmospheric Science)
Spring 2018: Meteo 580 (Communication of Meteorological Research)
Fall 2017: Meteo 597.3 (Physical Oceanography)
Spring 2017: Meteo 451 (Physical Oceanography)
Spring 2017: Geosc 410 (Marine Biogeochemistry, co-taught with Lee Kump)
Spring 2016: Meteo 421 (Atmospheric Dynamics)
Fall 2016: Meteo 580 (Communication of Meteorological Research)
Spring 2016: Meteo 421 (Atmospheric Dynamics)
Fall 2014: Meteo 300 (Fundamentals of Atmospheric Science)
Fall 2014: Meteo 421 (Atmospheric Dynamics)
Fall 2013: Meteo 597A (Dynamic Oceanography)
Fall 2013: Meteo 421 (Atmospheric Dynamics)
Fall 2012: Meteo 003 (Introductory Meteorology)
Fall 2012: Meteo 421 (Atmospheric Dynamics)
Fall 2011: Meteo 003 (Introductory Meteorology)
Fall 2011: Meteo 421 (Atmospheric Dynamics)
Spring 2010: Meteo 003 (Introductory Meteorology), Sections 1-4
Spring 2010: Meteo 003 (Introductory Meteorology), Sections 5-7
Fall 2010: Meteo 421 (Atmospheric Dynamics)
Fall 2010: Meteo 597G (Dynamic Oceanography)
Fall 2009: Meteo 300 (Fundamentals of Atmospheric Science)
Fall 2008: Meteo 520 (Geophysical Fluid Dynamics)
Fall 2008: Meteo 300 (Fundamentals of Atmospheric Science)
Fall 2007: Meteo 520 (Geophysical Fluid Dynamics)
Fall 2007: Meteo 300 (Fundamentals of Atmospheric Science)
Fall 2006: Geosc 410 (Marine Biogeochemistry)
Fall 2006: Meteo 520 (Geophysical Fluid Dynamics)
Fall 2005: Meteo 421 (Atmospheric Dynamics).
Fall 2004: Meteo 451 (Elements of Physical Oceanography)
Fall 2004: Meteo 520: Geophysical Fluid Dynamics
Spring 2003: Meteo/Geosc 475W (Global Biogeochemical Cycles)
Fall 2003: Meteo 451: Elements of Physical Oceanography
Fall 2003: Meteo 520: Geophysical Fluid Dynamics
Spring 2002: Meteo 597: The Global Carbon Cycle (with Ken Davis and Klaus Keller)
Spring 2002: Geosc 497 (Marine Biogeochemistry)
Fall 2002: Meteo 22 (The Oceans)
Fall 2002: Meteo/Geosc 588 (Oceans and Climate Seminar)
Spring 2001: Meteo 002/003L (Introductory Meteorology/Weather and Society)
Spring 2001: Meteo/Geosc 588 (Oceans and Climate Seminar)

Undergraduate internship graded (since 2001)

Fall 2020: Meteo 395A, Christopher Tate
Summer 2018: Meteo 495A, Harry Weinmann
Fall 2016: Meteo 495A, Matthew Dross
Spring 2016: Meteo 495C, Zachary Chabala
Spring 2015: Meteo 395C, Matthew Dross
Fall 2015: Meteo 395A, Zachary Chabala

Fall 2013: Meteo 495A, Benjamin Reppert
Fall 2011: Meteo 495, Brian Walder
Fall 2011: Meteo 495, Tia Grubbs
Spring 2010: Meteo 495, Sarah Kramb
Fall 2010: Meteo 495, Ian Frost
Fall 2009: Meteo 496, Ian Frost, Mike Griffith, Danielle Knittle, Joseph Leonardi, and Christopher Slocum
Fall 2008: Meteo 496, Alex Maldonado
Spring 2006: Meteo 496, Carrie McCabe
Fall 2006: Meteo 496, Allison O'Black
Fall 2006: Meteo 496, Armand Silva
Fall 2005: Meteo 496, Daniel Johnston, Kevin Aubele, and Amber Ortega
Fall 2002: Meteo 496, Ben Legg

Undergraduate research advised (since 2001)

Spring 2023: Meteo 494H, Jacqueline Kiszka
Spring 2023: Geosc 496, Caroline Spengler (Senior Thesis)
Fall 2022: Geosc 496, Caroline Spengler (Senior Thesis)
Summer 2021: Penn State's Research Experiences for Undergraduates (REU) in Climate Science, Alain Izabayo
Spring 2021: Geosc 496, Sarah Lehman (Senior Thesis)
Fall 2020: Meteo 494H, Catherine Kohlman
Fall 2020: Geosc 496, Sarah Lehman (Senior Thesis)
Summer 2020: Penn State's Research Experiences for Undergraduates (REU) in Climate Science, Paige Elliott
Spring 2020: Meteo 494M, Samantha Greaser
Spring 2020: Meteo 494M, Nicola Guisewhite
Summer 2018: Penn State's Research Experiences for Undergraduates (REU) in Climate Science, Jacob Cohen
Summer 2016: Penn State's Research Experiences for Undergraduates (REU) in Climate Science, Sebastián M. Cintrón Del Valle
Summer 2016: Penn State's REU in Climate Science, Geselle Coleman
Summer 2015: Penn State's REU in Climate Science, Hannah Wells
Summer 2014: Penn State's REU in Climate Science, Lauren Seidensticker
Summer 2013: Penn State's REU in Climate Science, Kate Colna
Spring 2014: Meteo 480W, Casey Dorn
Spring 2011: Meteo 480W, Andrew Ross
Fall 2010: Meteo 480W, Andrew Ross
Fall 2010: Meteo 480W, Joshua Magerman
Spring 2008: Meteo 480W, Leah Brandt, Maria Zatko, and Lauren Kasparek (also advised her as part of Women In Science and Engineering Research)
Spring 2007: Meteo 480W, Stefanie Zamorski and Chad Supek
Fall 2006: Meteo 496, Dustin Swales and Alexis Phillips
Fall 2006: Meteo 480W, Leigh Patterson
Fall 2006: Geosc 496, Allie Joswik
Spring 2006: Minority Undergraduate Research Experience, Richard Lam and Joshua Walker

Fall 2005: Meteo 496, Steven Greybush
Fall 2005: Meteo 480W, Brandon Katz, Leigh Patterson, and Matthew Porcelli
Summer 2004: Summer Research Opportunities Program, Myrna Hutcherson
Spring 2004: Meteo 496, Mark Zelinka
Summer 2002: Myrna Hutcherson, Summer Research Opportunities Program

Graduate degree committees (since 2010)

Tiffany Lewis (Current PhD Curriculum and Instruction)
Vikrant Sapkota (Current PhD Meteorology and Atmospheric Science)
Fai Chanchai (Current PhD Geosciences)
Christopher Sala (Current MS Meteorology and Atmospheric Science)
Colin Hawes (Current MS William & Mary)
Dani Buffa (Current PhD Anthropology)
Aoshuang Ji (Current PhD Geosciences)
Yifei Fan (2023 MS Meteorology and Atmospheric Science)
Yixuan Song (2023 PhD Mechanical Engineering)
Kyle Hinson (2023 PhD William & Mary)
Benjamin Barnes (2022 PhD Geosciences)
Jesus Ruiz-Plancarte (2020 PhD Meteorology)
Rebecca Payne (2020 PhD Geosciences)
Shelby Lyons (2020 PhD Geosciences)
Wenfei Ni (2019 PhD University of Maryland)
Moges Wagena (2018 PhD Virginia Tech)
Qian Li (2018 PhD Meteorology)
Alex Libardoni (2017 PhD Meteorology)
Caroline Normile (2017 PhD Meteorology)
Amanda Walker (2017 MS Meteorology)
Isaac Irby (2017 PhD William & Mary)
Andra Reed (2016 PhD Meteorology)
Benjamin Green (2015 PhD Meteorology)
Daniel Brouillette (2015 MS Meteorology)
Stephanie Hay (2014 MS Meteorology)
Ying Cui (2014 PhD Geosciences)
Yongjin Xiao (2013 PhD William & Mary)
Tae-Wook Kim (2012 PhD Pohang University of Science and Technology)
Liang Ning (2012 PhD Meteorology)
Leah Schneider (2012 PhD Geosciences)
Timothy Hilton (2011 PhD Meteorology)
Daniel Sarmiento (2011 MS Meteorology)
Martha Butler (2010 PhD Meteorology)
Roman Tonkonojenkov (2010 MS Meteorology)

Masters students supervised

Patrick Maloit (1998), Dominic Preiswerk (1998), Jody Gibson (1999), Jennifer Werner (2001), Andrew Decandis (2003), Ryan Cleary (2003), Robert Long (2004), Kathleen Bailey (2005), Timothy Hilton (2005), Karen Tinklepaugh (2006), Brandon Katz (2009),

Joshua Magerman (2013), Daniel Tomaso (2013), Andrew Ross (2013), and Ryan Creedon (2016)

Ph.D. students supervised

Maria Herrmann (2010), Justin Schulte (2015), and Andrew Ross (2017)

Post-doctoral scholars supervised

Ferial Louanchi (1998–2000), Karsten Friis (2003–2005), Xin Jin (2005–2006), Jill Arriola (2020–2022), Alexander López (2020–2021), and Seyi Ajayi (2023–present)

Research faculty supervised

Maria Herrmann (2014–present), Jill Arriola (2013–present)

Others supervised

Douglas Martins (2015), Alana Menendez (2015), Sreece Goldberger (2016), and Sonya Miller (2016)

3. Research

Journal articles

100. Rosentreter, J.A., Laruelle, G.G., Bange, H.W., Bianchi, T.S., Busecke, J.J., Cai, W.-J., Eyre, B.D., Forbrich, I., Kwon, E.Y., Maavara, T., Moosdorf, N., Najjar, R.G., Sarma, V.V.S.S., Van Dam, B. and Regnier, P., 2023. Coastal vegetation and estuaries are collectively a greenhouse gas sink. Nature Climate Change. doi: 10.1038/s41558-023-01682-9.

99. Hinson, K.E., Friedrichs, M.A.M., Najjar, R.G., Herrmann, M., Bian, Z., Bhatt, G., St-Laurent, P., Tian, H. and Shenk, G., 2023. Impacts and uncertainties of climate-induced changes in watershed inputs on estuarine hypoxia. Biogeosciences, 20: 1937-1961. doi: 10.5194/bg-20-1937-2023.

98. Shen, C., Testa, J.M., Herrmann, M. Najjar, R.G., 2022. Decoupling of estuarine hypoxia and acidification as revealed by historical water quality data. Environmental Science & Technology. doi: 10.1021/acs.est.2c05949

97. Xu, M., Hu, C., Najjar, R. G., Herrmann, M., Briceno, H., Barnes, B. B., J. O. R. Johansson, J. O. R., English, D. 2022. Estimating estuarine primary production using satellite data and machine learning. International Journal of Applied Earth Observation and Geoinformation, 110, doi: 10.1016/j.jag.2022.102821.

96. Regnier, P., Resplandy, L., Najjar, R. G., Ciais, P. 2021. The land-to-ocean loops of the global carbon cycle. Nature, 603, 401–410, doi: 10.1038/s41586-021-04339-9.

95. Liu, P., Liu, J., Ji, A., Reinhard, C. T., Planavsky, N. J., Babikov, D., Najjar, R. G., Kasting, J. F. 2021. Triple oxygen isotope constraints on atmospheric O_2 and biological productivity during the Mid-Proterozoic. Proceedings of the National Academy of Sciences, 118:51, doi: 10.1073/pnas.2105074118.

94. López, A. G., Najjar, R. G., Friedrichs, M. A. M., Wardrop, D. H., Hickner, M. A. 2021. Estuaries as filters for riverine microplastics: Simulations in a large, coastal-plain estuary. Frontiers in Marine Science, 8:715924, doi: 10.3389/fmars.2021.715924.

93. Yao, Y., Tian, H., Pan, S., Najjar, R. G., Bian, Z., Friedrichs, M. A. M., Li, H.-Y., Hofmann, E. E. 2021. A century-long history of aquatic carbon cycling in the Chesapeake and Delaware Bay Watersheds: modeling lateral transport, burial, and degassing of riverine carbon. Journal of Geophysical Research: Biogeosciences, 126, doi: 10.1029/2020JG005968.

92. Pan, S., Bian, Z., Tian, H., Yao, Y., Najjar, R. G., Friedrichs, M. A. M., Hofmann, E. E., Xu, R., Zhang, B. 2021. Impacts of multiple environmental changes on long-term nitrogen loading from the Chesapeake Bay Watershed. Journal of Geophysical Research: Biogeosciences 126, doi: 10.1029/2020JG005826.

91. Hinson, K., Friedrichs, M. A. M., St-Laurent, P., Da, F., Najjar, R. G. 2021. Extent and causes of Chesapeake Bay warming. Journal of the American Water Resources Association. doi: 10.1111/1752-1688.12916

90. Da, F., Friedrichs, M. A. M., St-Laurent, P., Shadwick, E. H., Najjar, R. G., Hinson, K. 2021. Mechanisms driving decadal changes in the carbonate system of a coastal plain estuary. Journal of Geophysical Research: Oceans, 126. doi: 10.1029/2021JC017239.

89. St-Laurent, P., Friedrichs, M.A.M., Najjar, R.G., Shadwick, E.H., Tian, H., Yao, Y., Stets, E.G., 2020. Relative impacts of global changes and regional watershed changes on the inorganic carbon balance of the Chesapeake Bay. Biogeosciences, in press, doi: 10.5194/bg-2020-117.

88. Herrmann, M., Najjar, R.G., Da, F., Friedman, J., Friedrichs, M.A.M., Goldberger, S., Menendez, A., Shadwick, E., Stets, E.G., St-Laurent, P., 2020. Challenges in quantifying air–water carbon dioxide flux using estuarine water quality data: Case study for Chesapeake Bay. Journal of Geophysical Research: Oceans 125, doi: 10.1029/2019JC015610.

87. Ross, A.C., Najjar, R.G., Li, M., 2020. A metamodel-based analysis of the sensitivity and uncertainty of the response of Chesapeake Bay salinity and circulation to projected climate change. Estuaries and Coasts, doi: 10.1007/s12237-020-00761-w.

86. Feagin, R.A., Forbrich, I., Huff, T.P., Barr, J.G., Ruiz-Plancarte, J., Fuentes, J.D., Najjar, R.G., Vargas, R., Vázquez-Lule, A.L., Windham-Myers, L., Kroeger, K.D., Ward, E.J., Moore, G.W., Leclerc, M., Krauss, K.W., Stagg, C.L., Alber, M., Knox, S.H., Schäfer, K.V.R., Bianchi, T.S., Hutchings, J.A., Nahrawi, H., Noormets, A., Mitra, B., Jaimes, A., Hinson, A.L., Bergamaschi, B., King, J.S., 2020. Tidal wetland gross primary production (GPP) across the continental United States, 2000–2019. Global Biogeochemical Cycles, doi: 10.1029/2019GB006349.

85. Hutchings, J.A., Bianchi, T.S., Najjar, R.G., Herrmann, M., Kemp, W.M., Hinson, A.L., Feagin, R.A., 2020. Carbon deposition and burial in estuarine sediments of the contiguous United States. Global Biogeochemical Cycles, doi: 10.1029/2019GB006376.

84. Najjar, R.G., Herrmann, M., Cintrón Del Valle, S.M., Friedman, J.R., Friedrichs, M.A.M., Harris, L.A., Shadwick, E.H., Stets, E.G., Woodland, R.J., 2020. Alkalinity in tidal tributaries of the Chesapeake Bay. Journal of Geophysical Research: Oceans 125. doi: 10.1029/2019JC015597.

83. Friedman, J.R., Shadwick, E.H., Friedrichs, M.A.M., Najjar, R.G., De Meo, O.A., Da, F., Smith, J.L., 2020. Seasonal variability of the CO_2 system in a large coastal plain estuary. Journal of Geophysical Research: Oceans 125. doi: 10.1029/2019JC015609.

82. Ni, W., Li, M., Ross, A. C., Najjar, R. G., 2019. Large projected decline in dissolved oxygen in a eutrophic estuary due to climate change. Journal of Geophysical Research: Oceans 124, 8271–8289.

81. Ross, A.C., Najjar, R.G., 2019. Evaluation of methods for selecting climate models to simulate future hydrological change. Climatic Change 157, 407–428.

80. Shadwick, E.H., Friedrichs, M.A.M., Najjar, R.G., De Meo, O.A., Friedman, J.R., Da, F., Reay, W.G., 2019. High-frequency CO_2 system variability over the winter-to-spring transition in a coastal plain estuary. Journal of Geophysical Research: Oceans 124, 7626–7642.

79. Signorini, S.R., Mannino, A., Friedrichs, M.A.M., St-Laurent, P., Wilkin, J., Tabatabai, A., Najjar, R.G., Hofmann, E.E., Da, F., Tian, H., Yao, Y., 2019. Estuarine dissolved organic carbon flux from space: with application to Chesapeake and Delaware Bays. Journal of Geophysical Research: Oceans 124, 3755–3778.

78. Fennel, K., Alin, S.R., Barbero, L., Evans, W., Bourgeois, T., Cooley, S.R., Dunne, J., Feely, R.A., Hernandez-Ayon, J.M., Hu, C., Hu, X., Lohrenz, S.E., Muller-Karger, F., Najjar, R.G., Robbins, L., Shadwick, E.H., Siedlecki, S., Steiner, N., Sutton, A., Turk, D., Vlahos, P., Wang, Z.A., 2019. Carbon cycling in the North American coastal ocean: A synthesis. Biogeosciences 16, 1281–1304.

77. Friedrichs, M.A.M., St-Laurent, P., Xiao, Y., Hofmann, E., Hyde, K., Mannino, A., Najjar, R.G., Narváez, D., Signorini, S.R., Tian, H., Wilkin, J., Yao, Y., Xue, J., 2019. Ocean circulation causes strong variability in Mid-Atlantic Bight net community production. Journal of Geophysical Research: Oceans 124, 1–22.

76. Najjar, R.G., Herrmann, M., Alexander, R., Boyer, E.W., Burdige, D.J., Butman, D., Cai, W.-J., Canuel, E.A., Chen, R.F., Friedrichs, M.A.M., Feagin, R.A., Griffith, P.C., Hinson, A.L., Holmquist, J.R., Hu, X., Kemp, W.M., Kroeger, K.D., Mannino, A., McCallister, S.L., McGillis, W.R., Mulholland, M.R., Pilskaln, C.H., Salisbury, J., Signorini, S.R., St-Laurent, P., Tian, H., Tzortziou, M., Vlahos, P., Wang, Z.A., Zimmerman, R.C., 2018. Carbon budget of tidal wetlands, estuaries, and shelf waters of Eastern North America. Global Biogeochemical Cycles 32, 389–416.

75. Wagena, M.B., Collick, A.S., Ross, A.C., Najjar, R.G., Rau, B., Sommerlot, A.R., Fuka, D.R., Kleinman, P.J.A., Easton, Z.M., 2018. Impact of climate change and climate anomalies on hydrologic and biogeochemical processes in an agricultural catchment of

the Chesapeake Bay Watershed, USA. Science of the Total Environment 637–638, 1443–1454.

74. Sedwick, P.N., Bernhardt, P.W., Mulholland, M.R., Najjar, R.G., Price, L.M., Sohst, B.M., Sookhdeo, C., Widner, B., 2018. Assessing phytoplankton nutritional status and potential impact of wet deposition in seasonally oligotrophic waters of the Mid-Atlantic Bight. Geophysical Research Letters 45, 3203–3211.

73. Cao, F., Tzortziou, M., Hu, C., Mannino, A., Fichot, C.G., Del Vecchio, R., Najjar, R.G., Novak, M.G., 2018. Remote sensing retrievals of colored dissolved organic matter and dissolved organic carbon dynamics in North American estuaries and their margins. Remote Sensing of Environment 205, 151-165.

72. Bannon, P.R., Najjar, R.G., 2018. Heat-engine and entropy-production analyses of the world ocean. Journal of Geophysical Research: Oceans 123, 8532–8547.

71. Walker, A., Titley, D.W., Mann, M.E., Najjar, R.G., Miller, S.K., 2018. A fiscally based scale for tropical cyclone storm surge. Weather and Forecasting 33, 1709–1723.

70. Seidensticker, L., Najjar, R.G., Herrmann, M., Boyer, J.N., Briceño, H.O., Kemp, W.M., Tomaso, D., 2018. Seasonal and interannual variability in net ecosystem production of a subtropical coastal lagoon inferred from monthly oxygen surveys. Estuaries and Coasts.

69. St-Laurent, P., Friedrichs, M.A.M., Najjar, R.G., Herrmann, M., Miller, S., Martins, D., Wilkin, J., 2017. Impacts of atmospheric nitrogen deposition on surface waters of the Western North Atlantic mitigated by multiple feedbacks. Journal of Geophysical Research: Oceans 122, 8406–8426.

68. Ross, A.C., Najjar, R.G., Li, M., Lee, S.B., Zhang, F., Liu, W., 2017. Fingerprints of sea-level rise on changing tides in the Chesapeake and Delaware Bays. Journal of Geophysical Research: Oceans 122, 8102–8125.

67. Schulte, J., Najjar, R.G., Lee, S., 2017. Streamflow and salinity variability in the Mid-Atlantic Region of the United States and its relationship with large-scale atmospheric circulation patterns. Journal of Hydrology 550, 65-79.

66. Orr, J.C., Najjar, R.G., Aumont, O., Bopp, L., Bullister, J.L., Danabasoglu, G., Doney, S.C., Dunne, J.P., Dutay, J.C., Graven, H., Griffies, S.M., John, J.G., Joos, F., Levin, I., Lindsay, K., Matear, R.J., McKinley, G.A., Mouchet, A., Oschlies, A., Romanou, A., Schlitzer, R., Tagliabue, A., Tanhua, T., Yool, A., 2017. Biogeochemical protocols and diagnostics for the CMIP6 Ocean Model Intercomparison Project (OMIP). Geosci. Model Dev. 10, 2169-2199.

65. Hinson, A.L., Feagin, R.A., Eriksson, M., Najjar, R.G., Herrmann, M., Windham-Myers, L., Bianchi, T.S., Holmquist, J.R., Kroeger, K.D., Gonneea, M., Kemp, M., Hutchings, J.A., Crooks, S., Boutton, T., 2017. The spatial distribution of soil organic carbon in tidal wetland soils of the continental United States. Global Change Biology 23, 5468–5480.

64. Martins, D., Najjar, R.G., Tzortziou, M., Abuhassan, N., Thompson, A.M., Kollonige, D.W., 2016. Spatial and temporal variability of ground and satellite column measurements of NO_2 and O_3 over the Atlantic Ocean during the Deposition of Atmospheric Nitrogen to Coastal Ecosystems Experiment (DANCE). Journal of Geophysical Research: Atmospheres 121, 14,175–114,187.

63. Schulte, J., Najjar, R.G., Li, M., 2016. The influence of climate modes on streamflow in the Mid-Atlantic Region of the United States. Journal of Hydrology: Regional Studies 5, 80-99.

62. DeVanna Fussell, K.M., Smith, R.E.H., Fraker, M.E., Boegman, L., Frank, K.T., Miller, T.J., Tyson, J.T., Arend, K.K., Boisclair, D., Guildford, S.J., Hecky, R.H., Höök, T.O., Jensen, O.P., Llopiz, J.K., May, C.J., Najjar, R.G., Rudstam, L.G., Taggart, C.T., Rao, Y.R., Ludsin, S.A., 2016. A perspective on needed research, modeling, and management approaches that can enhance Great Lakes fisheries management under changing ecosystem conditions. Great Lakes Research 42, 743–752.

61. Yu, X., Bhatt, G., Duffy, C.D., Wardrop, D.H., Najjar, R.G., Ross, A.C., Rydzik, M., 2015. A coupled surface–subsurface modeling framework to assess the impact of climate change on freshwater wetlands. Climate Research 66, 211-228.

60. Mannino, A., Signorini, S., Novak, M., Wilkin, J., Friedrichs, M., Najjar, R.G., 2016. Dissolved organic carbon fluxes in the Middle Atlantic Bight: An integrated approach based on satellite data and ocean model products. Journal of Geophysical Research: Biogeosciences, 121, 312–336.

59. Schulte, J., Najjar, R.G., Li, M., 2016. The influence of climate modes on streamflow in the Mid-Atlantic Region of the United States. Journal of Hydrology: Regional Studies, 5, 80–99.

58. Yang, Q.C., Tian, H.Q., Friedrichs, M.A.M., Hopkinson, C.S., Lu, C., 2015. Enhanced nitrogen export to the North America East Coast in response to multiple global changes from 1901 to 2008. Journal of Geophysical Research: Biogeosciences, 120, 1046–1068.

57. Tomaso, D., Najjar, R.G., 2015. Long-term variations in the dissolved oxygen budget of an urbanized tidal river: The Upper Delaware Estuary. Journal of Geophysical Research: Biogeosciences, 120, 1027–1045.

56. Tian, H.Q., Yang, Q.C., Najjar, R.G., Ren, W., Friedrichs, M.A.M., Hopkinson, C.S., Pan, S., 2015. Anthropogenic and climatic influences on carbon fluxes from eastern North America to the Atlantic Ocean: A process-based modeling study. Journal of Geophysical Research: Biogeosciences, 120, 752–772.

55. Herrmann, M., Najjar, R.G., Kemp, W.M., Alexander, R.B., Boyer, E.W., Cai, W.-J., Griffith, P.C., Kroeger, K.D., McCallister, S.L., Smith, R.A.., 2015. Net ecosystem production and organic carbon balance of U.S. East Coast estuaries. Global Biogeochemical Cycles, 29, 96–11.

54. Schulte, J.A., Duffy, C., and Najjar, R.G., 2015. Geometric and topological approaches to significance testing in wavelet analysis. Nonlinear Processes in Geophysics, 22, 139–156.

53. Ross, A.C., Najjar, R.G., Li, M., Mann, M., Ford, S., Katz, B., 2015. Sea-level rise and other influences on decadal-scale variations of salinity in a coastal plain estuary. Estuarine Coastal and Shelf Science, 157, 79–92.

52. Barr, J.G., Troxler, T., Najjar, R., 2014. Understanding coastal carbon cycling using top-down and bottom-up approaches. Eos, Transactions American Geophysical Union, 95, 315–316.

51. Bannon, P.R., Najjar, R., 2014. Available energy of the world ocean. Journal of Marine Research, 72, 219–242.

50. Signorini, S., Mannino, A., Friedrichs, M.A.M., Najjar, R.G., Cai, W.-J., Salisbury, J.E., Wang, Z.A., Thomas, H., Shadwick, E., 2013. Surface ocean pCO_2 seasonality and sea-air CO_2 flux estimates for the North American east coast. Journal of Geophysical Research, 118, 5439–5460.

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48. Ning, L., Mann, M.E., Crane, R., Wagener, T., Najjar, R.G., Singh, R., 2012. Probabilistic projections of anthropogenic climate change impacts on precipitation for the Mid-Atlantic Region of the United States. Journal of Climate, 25, 5273-5291.

47. Herrmann, M., Najjar, R.G., Neeley, A.R., Vila-Costa, M., Dacey, J.W., DiTullio, G.R., Kieber, D.J., Kiene, R.P., Matrai, P.A., Simó, R., Vernet, M., 2012. Diagnostic modeling of dimethylsulfide (DMS) production at two sites west of the Antarctic Peninsula. Continental Shelf Research, 32, 96–109.

46. Kim, T.-W., Lee, K., Najjar, R.G., Jeong, H.-D., Jeong, H.J., 2011. Increasing N abundance in the Northwestern Pacific Ocean due to atmospheric nitrogen deposition. Science 334, 505–509.

45. Katz, B., Najjar, R., Cronin, T., Rayburn, J., Mann, M.E., 2011. Constraints on Lake Agassiz discharge through the late-glacial Champlain Sea (St. Lawrence Lowlands, Canada) using salinity proxies and an estuarine circulation model. Quaternary Science Reviews, 30, 3248–3257.

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43. Najjar, R.G., Pyke, C.R., Adams, M.B., Breitburg, D., Hershner, C., Kemp, M., Howarth, R., Mulholland, M., Paolisso, M., Secor, D., Sellner, K., Wardrop, D., Wood,

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Invited presentations (2020–2022)

Najjar, R.G., Herrmann, M., López, A., St-Laurent, P. and Friedrichs, M.A.M., 2022. Evaluation of a model of Delaware Bay biogeochemistry, Integrated Coastal Ocean Modeling All-Hands Meeting, Baltimore, MD, October 18–19, 2022.

Najjar, R.G. and Herrmann, M., 2022. Tampa Bay net ecosystem production, 1976–2020, Tampa Bay Estuary Program Technical Advisory Committee Meeting, Virtual, October 19, 2022.

Najjar, R.G., 2022. Land-to-ocean loops of the global carbon cycle, Ocean Carbon and Biogeochemistry Summer Workshop, Woods Hole, MA, June 20, 2022.

Najjar, R.G., 2022. What determines how well an estuary neutralizes acids? A case study of alkalinity in the Chesapeake Bay's tidal tributaries, NOAA National Ocean Service Science Seminar Series, Virtual, March 24, 2022.

Najjar, R.G., 2022. How bad is plastic pollution and what can we do about it?, Foxdale Village, State College, PA, January 4, 2022.

Najjar, R.G., 2022. Estuaries as filters for riverine microplastics: A modeling case study of the Chesapeake Bay, Fluid Dynamics Research Consortium, The Pennsylvania State University, University Park, PA, February 17, 2022

Najjar, R.G., 2022. Land-to-ocean loops of the global carbon cycle, Earth System Science Center Seminar Series, The Pennsylvania State University, University Park, PA, February 9, 2022.

Najjar, R. G. 2021. Sea-level rise in Chesapeake Bay: A short review of the science. Chesapeake Research Consortium Roundtable on "Keeping Our Heads Above Water: Understanding Sea Level Rise Around the Bay," Virtual, February 17, 2021.

Najjar, R. G. 2021. The oceans and climate change. Foxdale Village Retirement Community, State College, PA, Virtual, January 13, 2021.

Najjar, R. G. 2021. How bad is plastic pollution and what can we do about it? Penn State Retirees Association, Rock Springs, PA, September 9, 2021.

Najjar, R. G. 2021. Climate change in the Mid-Atlantic Region. Mid-Atlantic Partnership Conference, Virtual, January 15, 2021.

Najjar, R. G., Friedrichs, M. A. M., Herrmann, M., Pan, S., Shadwick, E., St-Laurent, P., Stets, E., Tian, H., Yao, Y. 2021. Long-term changes in estuarine carbon cycling: The view from Chesapeake Bay Coasts and Estuaries Research Federation Conference, Virtual, November 1–4 and 8–11, 2021.

Najjar, R. G., Butman, D. E., Cai, W.-J., Fennel, K., Kolka, R., Trettin, C., Windham-Myers, L. 2021. Carbon cycling across the land–ocean aquatic continuum of North America, North American Carbon Program Open Science Meeting, Virtual, March, 2021.

Najjar, R.G., Herrmann, M., Cintron-Del Valle, S., Friedman, J., Friedrichs, M., Goldberger, S., Harris, L., Shadwick, E., Stets, E., Woodland, R., 2020. Alkalinity in tidal tributaries of the Chesapeake Bay. Virginia Institute of Marine Science, Interdisciplinary Marine Science Noon Seminar, Gloucester, VA (virtual presentation), October 30, 2020.

Najjar, R.G., Herrmann, M., Cintron-Del Valle, S., Friedman, J., Friedrichs, M.,

Goldberger, S., Harris, L., Shadwick, E., Stets, E., Woodland, R., 2020. Alkalinity in tidal tributaries of the Chesapeake Bay. Old Dominion University, Department of Ocean, Earth & Atmospheric Sciences, Norfolk, VA (virtual presentation), September 17, 2020.

Najjar, R.G., 2020. Regional and global views of carbon cycling in coastal waters. College of the Coast & Environment, Louisiana State University, Baton Rouge, LA (virtual presentation), October 23, 2020.

Najjar, R.G., 2020. Regional and global views of carbon cycling in coastal waters. Joint Earth Seminar Series, Institute of Arctic and Alpine Research, University of Colorado Boulder, Boulder, CO (virtual presentation), October 5, 2020.

Awards

Title: "Technical Report for the Delaware Estuary and River Basin 2022"
Sponsor: Partnership for the Delaware Estuary
Period of Performance: 6/1/2021–6/30/2022
Total Budget Requested: $10,000
Role: Principal Investigator

Title: "Transport and fate of microplastics in a tidal marsh ecosystem, Delaware Basin"
Sponsor: Penn State Institutes for Energy and the Environment
Period of Performance: 6/1/2022–5/31/2023
Total Budget Requested: $29,800
Role: Principal Investigator

Title: "Contaminants of emerging concern in impaired streams of the Delaware River watershed"
Sponsor: The Pennsylvania Water Resources Research Center (United States Geological Survey)
Period of Performance: 6/6/2022–2/20/2023
Total Budget Requested: $49,681
Role: Co-PI (Principal Investigator: L. Emili)

Title: "Integrated Coastal Modeling"
Sponsor: Battelle - Pacific Northwest National Laboratory
Period of Performance: 4/16/2020–9/30/2023
Total Budget Requested: $1,319,992
Role: Co-PI

Title: "Collaborative Research: How are Estuarine Carbon and Alkalinity Dynamics Influenced by Macrobiota?"
Sponsor: National Science Foundation
Period of Performance: 7/1/2022–6/30/2025
Total Budget Requested: $992,092
Role: Principal Investigator

Title: "The Baltimore Social-Environmental Collaborative IFL"
Sponsor: U.S. Department of Energy
Period of Performance: 9/1/2022–8/31/2023
Total Budget Requested: $6,371,823

Role: Co-Investigator

Title: “CHRP2016: Predicted Impacts of Climate Change on the Success of Alternative Management Actions in The Chesapeake Bay: Using Multiple Community Models in Support of Hypoxia Management”
Sponsor: National Oceanographic and Atmospheric Administration, via subcontract with Virginia Institute of Marine Science
Period of Performance: 9/1/2016–8/31/2023
Total Budget Requested: $198,386
Role: Principal Investigator

Title: “Response of Carbon Cycling to Climatic and Anthropogenic Perturbations in Two North American Subtropical Estuaries”
Sponsor: National Aeronautics and Space Administration
Period of Performance: 2/24/2017–2/23/2020
Total Budget Requested: $991,089
Role: Principal Investigator

Title: “Collaborative Research: Estuarine Metabolism and Gas Exchange Determined from Dissolved Oxygen Time Series: Method Development, Field Evaluation, and Application to Historical Data”
Sponsor: National Science Foundation
Period of Performance: 1/1/2020-12/31/2023
Total Budget Requested: $899,401
Role: Principal Investigator

Title: “REU Site: Interdisciplinary Climate Science Research at The Pennsylvania State University”
Sponsor: National Science Foundation
Period of Performance: 9/15/2019–8/31/2024
Total Budget Requested: $1,015,245
Role: Principal Investigator

Title: “Fate and Transport of Microplastics in Chesapeake Bay to Inform a Standard of Degradability”
Sponsor: College of Earth and Mineral Sciences, The Pennsylvania State University
Period of Performance: 2/1/2020–8/31/2021
Total Budget Requested: $105,000
Role: Principal Investigator

Title: “REU Site: Climate Science Research at The Pennsylvania State University”
Sponsor: National Science Foundation
Period of Performance: 5/1/2016–4/30/2020
Total Budget Requested: $362,034
Role: Principal Investigator

Title: “Collaborative Research: Multiple Stressors in the Estuarine Environment: What drives changes in the CO_2 system?”
Sponsor: National Science Foundation
Period of Performance: 10/1/2015–9/30/2020

Total Budget Requested: $180,000
Role: Principal Investigator

Title: “Vulnerability of the largest U.S. estuary to Acidification: Implications of declining pH for shellfish hatcheries in the Chesapeake Bay”
Sponsor: National Oceanographic and Atmospheric Administration, via subcontract with Virginia Institute of Marine Science
Period of Performance: 9/1/2018–8/31/2019
Total Budget: $23,000
Role: Principal Investigator
Award #: 721674-712683

Title: “The carbon budget of tidal wetlands and estuaries of the contiguous United States: a synthesis approach”
Sponsor: National Aeronautics and Space Administration
Period of Performance: 8/1/2014–5/31/2019
Total Budget: $1,634,966
Role: Principal Investigator
Award #: NNX14AM37G

Title: “Synergistic impacts of population growth, urbanization, and climate change on watersheds and coastal ecology of the northeastern United States”
Sponsor: National Aeronautics and Space Administration
Period of Performance: 3/19/2014–3/18/2019
Total Budget: $1,158,225
Role: Principal Investigator
Award #: NNX14AF93G

Title: “WSC-Category 1 Collaborative Proposal: Coupled Multi-scale Economic, Hydrologic, and Estuarine Modeling to Assess Impacts of Climate Change on Water Quality Management”
Sponsor: National Science Foundation
Period of Performance: 7/1/2014–6/30/2018
Total Budget: $119,829
Role: Principal Investigator
Award #: CBET-1360286

Title: “Technical Report for the Delaware Estuary and River Basin – 2017”
Sponsor: Partnership for the Delaware Estuary
Period of Performance: 8/12/2016–5/31/2017
Total Budget: $10,000
Role: Principal Investigator
Award #: 187734

Title: “Collaborative Research: Impacts of atmospheric nitrogen deposition on the biogeochemistry of oligotrophic coastal waters”
Sponsor: National Science Foundation
Period of Performance: 3/15/2013–2/28/2017
Total Budget: $386,113
Role: Principal Investigator

Award #: OCE-1260574

Title: “The Impact of climate modes on the Hudson River estuary”
Sponsor: Hudson River Foundation
Period of Performance: 9/1/2014–9/1/2015
Total Budget: $16,000
Role: Principal Investigator
Award #: GF/02/14

Title: “DEP Climate Report”
Sponsor: Pennsylvania Department of Environmental Protection
Period of Performance: 9/19/2011–6/30/2015
Total Budget: $98,326
Role: Co-Principal Investigator (PI: James Shortle)
Award #: 4400008014

Title: “Collaborative Research: Estuarine Response to Climate Forcing”
Sponsor: National Science Foundation
Period of Performance: 6/15/2010–5/31/2015
Total Budget: $331,155
Role: Principal Investigator
Award #: OCE-0961423

Title: “Impacts of Climate and Land Use Changes or Coastal Carbon Cycling: Observations, Analysis, and Modeling (REVISED)”
Sponsor: National Aeronautics and Space Administration, via subcontract with Virginia Institute of Marine Science
Period of Performance: 2/1/2011–1/31/2015
Total Budget: $156,584
Candidate’s Role: Principal Investigator
Award #: 715675-712683

Title: “Regional and global sea surface temperature reconstruction and the relationship with sea level during the late Holocene”
Sponsor: U.S. Geological Survey
Period of Performance: 5/1/2011–4/30/2013
Total Budget: $64,919
Role: Principal Investigator
Award #: G11AC20035

Title: “U.S. eastern Continental Shelf Carbon Cycling (USECoS): Modeling Data Assimilation and Analysis”
Sponsor: National Aeronautics and Space Administration, via subcontract with Virginia Institute of Marine Science
Period of Performance: 5/5/2008–4/30/2012
Total Budget: $131,524
Role: Principal Investigator
Award #: 713634/712683

Title: “Climate Change Indicators and Projections for the Delaware Estuary Watershed Based on Regional Dynamic Models-Phase 1 & 2”
Sponsor: Partnership for the Delaware Estuary
Period of Performance: 11/15/2010–6/15/2011
Total Budget: $15,000
Role: Principal Investigator
Award #: PDE 140-05

Title: “Chesapeake Basin Simulated Loads under Scenarios of Climate Change”
Sponsor: Chesapeake Research Consortium, Inc.
Period of Performance: 3/1/2011–5/31/2011
Total Budget: $10,000
Role: Co-Principal Investigator (PI: Denice Wardrop)
Award #: EPASTAC-1

Title: “Research Cruise Opportunity for Graduate Students”
Sponsor: University of California at San Diego
Period of Performance: 1/1/2010–5/31/2011
Total Budget: $5,739
Role: Principal Investigator
Award #: PO 10314158

Title: “Hydrologic Forecasting for Characterization of Non-linear Responses of Freshwater Wetlands to Climatic and Land Use Change in the Susquehanna River Basin, USA”
Sponsor: Environmental Protection Agency
Period of Performance: 4/20/2007–4/19/2011
Total Budget: $899,656
Role: Co-Principal Investigator (PI: Denice Wardrop)
Award #: 83301301

Title: “PA Climate Impact Assessment”
Sponsor: Pennsylvania Department of Environmental Protection
Period of Performance: 3/2/2009–6/30/2010
Total Budget: $193,954
Candidate’s Role: Co-Principal Investigator (PI: James Shortle)
Award #: 4400003640

Title: “Analysis of Climate simulations of Lagos State, Nigeria-Fixed Price Agreement”
Sponsor: Triple E Systems
Period of Performance: 12/1/2009–5/31/2010
Total Budget: $18,000
Role: Principal Investigator
Award #: 118582

Title: “Climate Projections for the Delaware Estuary and Its Watershed”
Sponsor: Partnership for the Delaware Estuary
Period of Performance: 5/1/2009–1/31/2010
Total Budget: $3,000
Role: Principal Investigator

Award #: PDE 167-01

Title: “Development of a Model to Simulate Catastrophic Glacial Lake Discharges into the St. Lawrence–Champlain Valleys”
Sponsor: U.S. Department of the Interior
Period of Performance: 1/1/2007–12/31/2008
Total Budget: $58,000
Role: Principal Investigator
Award #: 07ERAG0002

Title: “Eastern U.S. Continental Shelf Carbon Budget: Modeling, Data Assimilation, and Analysis”
PI: Raymond Najjar
Sponsor: National Aeronautics and Space Administration
Period of Performance: 7/1/2004–6/30/2008
Total Budget: $164,100
Role: Principal Investigator
Award #: NNG04GO23G

Title: “Analysis of Nutrient Budgets and Carbon Export in the Eastern and Western Subtropical North Atlantic Ocean”
Sponsor: National Aeronautics and Space Administration
Period of Performance: 6/1/2004–5/31/2008
Total Budget: $209,342
Role: Principal Investigator
Award #: NNG04GL67G

Title: “Collaboration: Biocomplexity: Complex Molecular to Global Interactions and Feedbacks in the Marine DMS Cycle”
Sponsor: Bigelow Laboratory for Ocean Sciences (NSF Primary)
Period of Performance: 1/1/2003–11/30/2007
Total Budget: $230,558
Role: Principal Investigator
Award #: 2003-3

Title: “Global Modeling of Air–Sea Carbon and Oxygen Fluxes”
Sponsor: National Oceanic and Atmospheric Administration
Period of Performance: 9/1/2002–8/31/2007
Total Budget: $229,338
Role: Principal Investigator
Award #: NA16GP2987

Title: “Global Change Research Program (GCRP)”
Sponsor: Environmental Protection Agency
Period of Performance: 8/1/2002–12/31/2006
Total Budget: $749,984
Role: Research Associate (PI: Ann Fisher)
Award #: R-83053301-0

Title: “Collaborative Research: Production and Dissolution of Calcium Carbonate in the Global Ocean: A Synthesis and Modeling Project”
PI: Raymond Najjar
Sponsor: National Science Foundation
Period of Performance: 3/15/2002–2/28/2006
Total Budget: $143,659
Role: Principal Investigator
Award #: OCE-0136621

Title: “Detection of Estuarine Salinity Change Due to Sea-Level Rise”
Sponsor: National Science Foundation
Period of Performance: 9/15/2004–8/31/2005
Total Budget: $58,966
Role: Principal Investigator
Award #: OCE-0444005

Title: “Seasonal Biogeochemical Cycling of CO, OCS, and HOOH in the Sargasso Sea: Measuring and Modeling Distribution, Fluxes, and Processes”
Sponsor: National Science Foundation
Period of Performance: 10/1/1998–9/30/2002
Total Budget: $71,514
Role: Principal Investigator
Award #: OCE-9815179

Title: “Ocean Circulation and Biogeochemistry During the Maastrichtian”
Sponsor: National Science Foundation
Period of Performance: 8/1/1999–7/31/2002
Total Budget: $145,778
Role: Co-Principal Investigator (PI: Michael Arthur)
Award #: OCE-9975107

Title: “Evaluation and Intercomparison of Three-Dimensional Marine Carbon Cycle Models”
Sponsor: National Aeronautics and Space Administration
Period of Performance: 1/1/1998–12/31/2001
Total Budget: $201,866
Role: Principal Investigator
Award #: NAG5-6451

Title: “Determination of Regional- and Global-Scale New Production, Remineralization Rates and DOC Fluxes from the Annual Cycle of Oxygen in the Upper Ocean”
Sponsor: National Science Foundation
Period of Performance: 10/1/1997–9/30/2001
Total Budget: $192,431
Role: Principal Investigator
Award #: OCE-9711937

Title: “Modeling the Air–Sea Fluxes of Carbonyl Sulfide and Carbon Monoxide Using Remotely-Sensed Data”
Sponsor: National Aeronautics and Space Administration

Period of Performance: 9/1/1997–8/31/2001
Total Budget: $179,506
Candidate's Role: Principal Investigator
Award #: NAG5-6389

Title: "Assessment of the Response of the Ocean–Atmosphere System to the Evolution of the Southern Ocean During the Cenozoic"
Sponsor: National Science Foundation
Period of Performance: 2/15/1997–1/31/2000
Total Budget: $103,151
Role: Principal Investigator
Award #: ATM-9618025

Title: "Water Supply Impacts From Flooding Induced by Climate Change: Contamination Potential and Comparison of Prevention Versus Mitigation"
Sponsor: Environmental Protection Agency, via subcontract with Johns Hopkins University
Period of Performance: 10/1/1996–9/30/1999
Total Budget: $421,765
Candidate's Role: Co-Principal Investigator (PI: Ann Fisher)
Award #: 63629

Title: "Simulation of Atmospheric Oxygen in the Community Climate Model"
Sponsor: National Aeronautics and Space Administration
Period of Performance: 1/1/1997–12/31/1998
Total Budget: $50,000
Role: Principal Investigator
Award #: NAG5-3976

Title: "Development of a Model Atmospheric Oxygen Variations to Estimate Terrestrial Carbon Storage and Release"
Sponsor: National Aeronautics and Space Administration
Period of Performance: 5/1/1994–10/31/1995
Total Budget: $83,500
Role: Principal Investigator
Award #: NAGW-3929

Title: "IPA Agreement"
Sponsor: U.S. Department of the Navy
Period of Performance: 10/1/1994–9/30/1995
Total Budget: $20,000
Role: Principal Investigator
Award #: UNNUMBERED IPA ASSIGNMENT AGT.

Title: "IPA Agreement"
Sponsor: U.S. Department of the Navy
Period of Performance: 4/1/1994–9/30/1994
Total Budget: $14,190
Role: Principal Investigator
Award #: UNNUMBERED IPA ASSIGNMENT A

4. Selected service

University

- Faculty senator and member of the Faculty Senate University Planning Committee (ended a 3-year term in May, 2022)
- Director, Climate Science Dual-Title Ph.D. Program (2019–present)
- Member of the Ad Hoc Committee on the Implementation of Graduate Faculty Nomination Evaluation Committee (GFNEC) Qualifications (2022–present)

College

- Chair of the EMS GFNEC (2010–2022, currently a member)
- Tri-chair (with N. Kiver and V. Sanchez) of working group to assess the living, learning, and working environment (ALLWE) in EMS (2018–present).
- Safety Officer
- Member of Operations Committee for Sustainability
- EESI affiliate and advisory committee member

Department

- Member Graduate Academic Program Committee (ended spring 2022)
- Member Undergraduate Academic Program Committee (starting fall 2022)

External

- Guest editor for an article in a special issue on "Aquatic Carbon Stocks and Fluxes: The Big Picture from Remote Sensing" in the journal *Earth-Science Reviews*, expected to be published in 2023.
- Proposal reviewer for National Science Foundation's Chemical Oceanography Program
- Member of working group on "Filling the gaps in observation-based estimates of air–sea carbon fluxes," sponsored by the Ocean Carbon and Biogeochemistry Program and led by Galen McKinley (Columbia University).
- *Bay Journal* Science Advisory Board Member
- Member of RECCAP2, the 'REgional Carbon Cycle Assessment and Processes', phase 2 (RECCAP-2), which is part of the Global Carbon Project. Main participation is within the Land–Ocean Aquatic Continuum Group.
- Expert Witness: Bowfin Keycon Holdings, LLC, et al. v. Pa. Dept. of Environmental Protection, Preliminary Injunction Hearing (May 11, 2022); Expert in Ocean and Atmospheric Science, Climate Change, and Climate Modeling.
- Co-chair of Scientific Leadership Group (SLG), North American Carbon Program (NACP), 2013–2017, member until 2019. The SLG provides scientific leadership for the NACP. The NACP SLG assists the Carbon Cycle Interagency Working Group and NACP Office in implementing the NACP Science Plan, following the Science Implementation Strategy adopted in 2004 and works to assure that scientific returns are maximized.

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

PETITION OF PECO ENERGY COMPANY FOR A FINDING OF NECESSITY

PURSUANT TO 53 P.S. § 10619

Docket No. P-2021-3024328

REMAND DIRECT TESTIMONY

WITNESS: JAMES CAPUZZI

SUBJECT: PROVIDE EXPERT TESTIMONY REGARDING THE RISKS AND SAFETY ISSUES ASSOCIATED WITH PECO'S PROPOSED GAS RELIABILITY STATION TO BE LOCATED AT 2090 SPROUL ROAD, MARPLE TOWNSHP, PA.

DATED: September 22, 2023

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REMAND DIRECT TESTIMONY OF JIM CAPUZZI

I. INTRODUCTION

Q. Please state your name and business address.

A. My name is Jim Capuzzi. My business address as Fire Marshall for Marple Township is 227 S. Sproul Road, Broomall, PA 19008

Q. What is your educational background?

A. I received the following degrees: Drexel University - BS, Civil Engineering, 1979, La Salle University - MBA, Risk Management & Insurance, 1986 and St. Joseph's University - MS, Environmental Protection & Safety Mgmt, 2011.

Q. Please describe your work experience relevant to your Direct Testimony.

A. I am currently the Fire Marshal for Marple Township and have held that position for over a decade. The Township Fire Marshall has all of the duties for enforcement of the Fire Prevention Code of the Township, which establishes regulations governing conditions hazardous to life and property from fire or explosion and includes the BOCA National Fire Prevention Code and the Life Safety Code of the National Fire Protection Association. Additionally, I am a Senior Consultant for Aon Global Risk Consulting of Philadelphia, Pennsylvania, where I am responsible for property risk control consulting services for a diverse book of business, including large multinational companies, and facilitating the resources of Aon Global Risk Consultants (AGRC). I have over 40 years of fire protection engineering, property risk control and related insurance brokerage experience. Previously, I was Director of Property Risk Control for Aon's Philadelphia operations, including responsibility for the HPR/property risk control consulting practice. Prior to joining Aon (Frank B. Hall & Co.) in 1987, I served as

a fire protection consultant and special representative with the Industrial Risk Insurers (IRI) - Philadelphia office.

Q. Do you have any other experience or professional certifications that would be relevant to your Direct Testimony?

A. Yes. I hold the professional designation CFPS (Certified Fire Protection Specialist). I am a voting member of the National Fire Protection Association. Additionally, I am a long-time member of Broomall Fire Company #53 and currently serve as its President.

II. PURPOSE OF TESTIMONY

Q. What is the purpose of your Remand Direct Testimony in this proceeding?

A. I provided Direct Testimony in the initial hearings in this matter. It is my understanding that the Commonwealth Court remanded the matter back to the Public Utility Commission to conduct a thorough environmental review of the building siting proposal, including issues such as impact radius, noise, or heater emissions. I had reviewed the testimony, documents and information submitted by PECO in these proceedings related to the Gas Reliability Station proposed for the 2090 Sproul Road property relative to fire or life safety matters in preparation for the initial testimony in this matter. I have been asked by the Township re affirm my prior testimony, updating same if necessary in light of the testimony offered by others at the initial hearings. The purpose of my testimony is to advise of issues, concerns and/or recommendations resulting from such review and to offer my professional opinion as to the suitability of the 2090 Sproul Road site for the proposed facilities from a fire and life safety standpoint.

Q. Are you sponsoring any exhibits?

A. Yes. I sponsored Exhibit JC-1, which is my professional resume or CV and Exhibit JC-2, which is the report I issued to the Township Director of Code Enforcement. I understand that my

prior testimony and the exhibits were previously admitted of record in this proceeding. I re-affirm my previous testimony, including exhibits,

III. FIRE MARSHAL REVIEW AND REPORT

Q. Please describe your review.

A. At the request of the Township Solicitor and after signing the required non-disclosure form, I reviewed PECO responses and supplemental responses to request for production of documents and to interrogatories. My review included the following documents: PECO 000762-000769 Safety Data Sheets, 000473-000520C Gas Emergency Response, Confidential 2500-2506 Response to Emergency generator alarm; Confidential 2799-2822 Tank information and safety data sheets; Confidential 3020-3026 Heater information; Confidential 3179-3223 Intertek surface burning report; Confidential 2731-2792 Due diligence report. On a separate occasion, Thomas Dobbins, Chief of Broomall Fire Company, and I had a call with representatives of PECO to discuss the proposed facility. I also reviewed the testimony of the various witnesses at the prior hearings in this matter.

Q. Did you have any findings relative to fire and life safety matters?

A. Yes.

Q. What were your findings?

A. As detailed in my report, my initial findings were the Safety Data Sheet for Natural Gas provided by PECO confirms that Natural Gas is an extremely flammable gas, easily ignitable and will form explosive mixtures in air. The Data Sheet also gives guidance to emergency responders when an accidental release occurs. This guidance tracks with the guidance presented in the US Department of Transportation 2020 Emergency Response Guide (ERG). Both documents call for an immediate isolation of the leak area for at least 100 meters (330 feet) in all

directions. This would mean that on the report of any leak at the proposed facility at a minimum the following evacuations must take place:

1. All homes on Cedar Grove Road between Sproul Road and Boxwood Dr.
2. All homes and businesses on Sproul between Parkway W and north of Cedar Grove Rd. (Including Freddy's and Fritch's)
3. The first 3 homes on the east side of Boxwood Dr. from Cedar Grove Rd.
4. The total shut-down of Sproul Road (PA Route 320).

If the leak is not immediately controlled this isolation area will need to be increased accordingly. I would also note that although I am concerned about the integrity of the underground piping, I am most concerned with the piping above ground and inside the proposed building which upon a breach would vent directly to the atmosphere.

I understand will not be manned, but remotely monitored and controlled. PECO has indicated that there will also be safety systems installed in the station aimed at mitigating potentially hazardous conditions. When written details of these systems are provided, I will review them the same as I do for any other new hazardous operation in the township.

With that said we all know that systems, no matter how redundant, are subject to failure and require human intervention to control an incident. Should there be a leak emanating from a pipe flange ahead of the main valve of the incoming gas line inside the Reliability Station it will be necessary to manually shut the valve in the street. Each second the leak goes unmitigated increases the potential for an explosion with widespread destruction of property and potentially the loss of life (both civilian and emergency responders).

Q. Are you aware that the Gas Reliability Station will be an unmanned facility?

A. Yes. The intent of the facility to be unmanned is a great concern and increases the likelihood of greater area of damage to property and person before mitigation can be accomplished. Of even greater concern is the location of the Gas Reliability Station at the proposed 2090 Sproul Road site. Given the densely populated immediately surrounding residential community and adjacent commercial shopping center, the potential for immediate and widespread damage to property and person in an emergency greatly increased. Having been involved in the fire service for over forty years and a Certified Fire Protection Specialist who sits on an NFPA committee, I strongly recommend the proposed Reliability Station not be built in the densely habituated area.

Q. Based on review and findings, do you have an opinion as to whether the location of Gas Reliability Station facilities as proposed by PECO at the 2090 Sproul Road site is appropriate and in the public interest.

A. I do.

Q. What is your opinion?

A. I originally offered that, or the reasons stated above, given the adjacent and immediate proximity to densely populated residential community and immediately adjacent busy restaurant and commercial shopping, coupled with the lack of information on emergency systems response, it is my opinion that the 2090 Sproul Road site is not an appropriate location for the proposed Gas Reliability Station from a fire and life safety standpoint, and therefore is not in the public interest. I would like to re-affirm that opinion and, giving additional consideration to the testimony of others in the initial hearings before the PUC, to reiterate my concerns from a fire and life-safety standpoint. In my professional opinion, based on over forty years of fire service and my experience and training as fire marshal and risk-management consultant certification as

Certified Fire Protection Specialist, that the siting of this facility at this site is not appropriate from a fire and life safety standpoint nor is it in the public interest. This opinion is based on the my initial review as contained in his the JC-1 report and testimony in the initial hearings which confirmed that a significant number of persons live, work and shop and many buildings are situated within the impact radius in the event of fire or other catastrophic event at the facility, coupled with the fact the facility will not be manned, PECO's projected response time and my ex experience with the Fire Company with respect to PECO's response time. Based on these factors, it appears that the damage to persons and property in such an event could be substantial, and, therefore, this facility should not be located or sited at the proposed site in such close proximity to person and property.

IV. CONCLUSION

Q. Does this conclude your Remand Direct Testimony?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

PETITION OF PECO ENERGY COMPANY FOR A FINDING OF NECESSITY

PURSUANT TO 53 P.S. § 10619

Docket No. P-2021-3024328

REMAND REBUTTAL TESTIMONY

WITNESS: JAMES CAPUZZI

SUBJECT: RESPOND TO THE TESTIMONY PROVIDED BY MIKE ISRANI ON BEHALF OF PECO ENERGY COMPANY REGARDING THE SAFETY OF PROPOSED NATURAL GAS RELIABILITY STATION TO BE LOCATED AT 2090 SPROUL ROAD, MARPLE TOWNSHIP, PA.

DATED: October 30, 2023

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REMAND REBUTTAL TESTIMONY OF JIM CAPUZZI

I. INTRODUCTION

Q. Q. Please state your name, business address and title.

A. My name is Jim Capuzzi. My business address as Fire Marshall for Marple Township is 227 S. Sproul Road, Broomall, PA 19008. I am currently the Fire Marshal for Marple Township.

Q. Have you previously submitted testimony in this proceeding?

A. Yes. I submitted remand direct testimony that is marked as Marple Township Remand Statement No. 4. My educational background, work experience and professional certifications are set forth in my remand direct testimony.

II. PURPOSE OF TESTIMONY

Q. Mr. Capuzzi, what is the purpose of your rebuttal testimony in this proceeding?

A. The purpose of my testimony is to respond to the testimony provided by Mike Israni on behalf of PECO Energy Company regarding the safety of the proposed natural gas reliability station to be located at 2090 Sproul Road, Marple Township and to advise of any changes in my professional opinion as to the suitability of the 2090 Sproul Road site for the proposed facilities from a fire and life safety standpoint following my review of Mike Israni's remand direct testimony and the remand direct testimony of Jeffrey D. Marx, P.E. on behalf of Marple Township.

III. RESPONSE TO MIKE ISRANI'S SAFETY REVIEW

Q. Please describe your review.

A. At the request of the Township Solicitor and after signing the required non-disclosure form, I reviewed the testimony and associated exhibits provided by Mike Israni on behalf of PECO Energy Company regarding the safety of the proposed natural gas reliability station to be

located at 2090 Sproul Road, Marple Township and also the remand direct testimony and associated exhibits provided by Jeffrey D. Marx, P.E. on behalf of Marple Township regarding the risk and potential hazards associated with PECO's proposed gas reliability station to be located at 2090 Sproul Road, Marple Township, PA.

Q. Did you have any findings or take issue with respect to the testimony and associated exhibits provided by Mike Israni relative to fire and life safety matters?

A. Yes.

Q. What were your findings and in what respect did you take issue with Mr. Israni's testimony?

A. Mr. Israni takes great pains to explain that the Potential Impact Radius (PIR) is referred to under the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) regulations. These regulations apply to natural gas transmission systems which generally cross state boundaries. PHMSA has no authority over distribution systems. He further argues that the PIR concept is "simply inapplicable to the Station" because it is part of PECO's distribution system. Although the calculation of and the mandate is included in the PHMSA regulation, I strongly disagree that it is "simply inapplicable". Natural gas pipelines, both transmission and distribution have the potential to leak and explode with devastating consequences.

Mr. Israni further infers that the typically lower pressure of the distribution system invalidates the calculation of the PIR. Since a primary variable in the PIR calculation is operating pressure, his statement is simply inaccurate.

In my mind, trying to make a distinction between gas transmission systems and distribution systems is like comparing local highways with interstate highways. Both carry

vehicles, generally at different speeds; and one is patrolled by State Troopers, the other by local police, but ultimately fatalities occur on both. PIR is a useful calculation in determining whether a facility such as the proposed gas reliability station is appropriate located in relation to neighboring population and property, as it provides guidance as to the potential impacts on the neighboring property and population in the event of adverse event.

Additionally, Mr. Israni took issue with the testimony of Mr. Tim Boyce, Delaware County's Emergency Management Director. However, the 2020 DOT Emergency Response Guide for a natural gas leak does call for the immediate evacuation of 100 meters (330 feet) and for large leaks at least 800 meters (.5 miles).

The point is the areas within both the PIR and the Emergency Response Guide evacuation guideline include inhabited structures and well-traveled highways, which will be adversely impacted in the event of fire, explosion or leak.

Q: Do you feel that Mr. Israni's testimony otherwise adequately evaluated potential safety impacts or concerns?

A. No.

Q: Please explain.

A. For example, Mr. Israni's testimony talks about incidents that have occurred at industry (including PECO) district regulating stations. I believe there is a distinct difference between a regulating station and the "reliability" station proposed for this site. A critical component of this reliability station is the heating of natural gas, something that does not happen at any PECO regulating station. The heating of any volatile gas significantly increases the potential for a small leak to form a vapor cloud. The heaters themselves become a source of ignition causing a vapor

cloud explosion. A vapor cloud then has the ability to travel well beyond the initial source which is justification for the DOT evacuation distances.

Q. Did your review of the remand direct testimony alter or change your concerns as voiced in your direct testimony regarding PECO proposed operation of the facility and procedures for dealing with leak or fire events?

A. No. My greatest concern is the inability of PECO to have personnel specifically trained for emergencies at the proposed reliability station to respond in a timely manner. Typically, emergency service providers including the Broomall Fire Company are told that a representative of PECO will respond to an emergency within 1 hour. Our experience has been that often times upon arrival, the PECO representative will need to have other resources dispatched to assist. For example, at a house fire in Haverford Township, PECO was called to disconnect the gas and electric services. The first PECO representative removed the electric meter, shutting power to the house. As he turned to walk away, I asked him about securing the gas service and his response was it was not his responsibility. We had to wait for another PECO employee to shut the gas.

~~Another example, it is my understanding that a recent gas explosion in Yeadon, Delaware County was a result of a delayed response by PECO to a downed primary electrical line that subsequently energized the area which was likely the result of the ignition of a gas pocket formed by a deteriorated distribution pipe.~~

Additionally, PECO takes measures to protect the locations of their regulating stations. In most cases these are hidden by fences and/or natural buffers. A primary reason is to protect the installation from vandals and others seeking to do harm. As part of the FEMA Assistance to Firefighters Grant Program we are asked to report “critical infrastructure” within our first

response area. Without question this proposed facility will top that list and an incident at the facility will result in major ramifications for the entire township.

Q. Based on review and findings, do you have still have an opinion as to whether the location of Gas Reliability Station facilities as proposed by PECO at the 2090 Sproul Road site is appropriate and in the public interest.

A. I do.

Q. What is your opinion?

A. I originally offered that, for the reasons stated in my original direct testimony and my remand direct testimony, given the adjacent and immediate proximity to densely populated residential community and immediately adjacent busy restaurant and commercial shopping, coupled with the lack of information on emergency systems response, it is my opinion that the 2090 Sproul Road site is not an appropriate location for the proposed Gas Reliability Station from a fire and life safety standpoint, and therefore is not in the public interest. I again would like to re-affirm that opinion and, giving additional consideration to the testimony of others in the initial hearings before the PUC, to reiterate my concerns from a fire and life-safety standpoint. I would like to restate that, in my professional opinion, based on over forty years of fire service and my experience and training as fire marshal and risk-management consultant certification as Certified Fire Protection Specialist, that the siting of this facility at this site is not appropriate from a fire and life safety standpoint nor is it in the public interest. This opinion is based on the my initial review as contained in my testimony in these proceedings and the testimony in the initial hearings of others which confirmed that a significant number of persons live, work, shop and travel within the PIR and evacuation areas and many buildings and structures are situated within the impact radius in the event of fire or other catastrophic event at

the facility, the fact the facility will not be manned, PECO's projected response time and my experience with the Fire Company with respect to PECO's response time. Based on these factors, it appears that the damage to persons and property in such an event could be substantial, and, therefore, this facility should not be located or sited at the proposed site in such close proximity to person and property.

IV. CONCLUSION

Q. Does this conclude your Remand Rebuttal Testimony?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

VERIFICATION

I, James Capuzzi, hereby verify that the facts set forth in the foregoing Remand Rebuttal Written Testimony is true and correct to the best of my knowledge, information and belief, and that these statements are made subject to the penalties of 18 Pa. C.S. §4909, relating to unsworn falsification to authorities.

Date: October 30, 2023

James Capuzzi

Jim Capuzzi

Senior Consultant
Aon Global Risk Consulting / Philadelphia, PA

Current Responsibilities:	Jim Capuzzi is responsible for property risk control consulting services for a diverse book of business, including large multinational companies, and facilitating the resources of Aon Global Risk Consultants (AGRC). Jim possesses expertise in providing risk management consulting and in developing creative risk control solutions for a diverse client-base encompassing manufacturing; pharmaceutical/chemical; hospitality; entertainment; financial services; real estate and portfolio companies. Jim serves as a client advocate, providing consulting services including effective fire protection, property risk control and loss control solutions on a global basis with customers, consultants, carriers and vendors.
Special Areas of Expertise:	Property Risk Control: Due Diligence Flood Zone Determination HPR Trained - GE Gaps/IRI Former Employee Plan Review (Sprinkler/Construction) Risk Control Surveys Business Interruption & Contingent Business Interruption Analysis Account Risk & Recommendation Analysis Rapid Response: Team Member Level III
Prior Industry Experience:	Jim's' career spans over 40 years of fire protection engineering, property risk control and related insurance brokerage experience. The former Director of Property Risk Control for Aon's Philadelphia operations including the Hershey office, he was responsible for HPR/property risk control consulting practice. He managed a staff of HPR-trained property risk control consultants and provided direction, support and resources to the ARS client base. Specializing in delivery of global HPR property risk control services to diversified manufacturing, pharmaceutical/chemical, financial services, hospitality, entertainment and real estate and service Industries. Prior to joining Aon (Frank B. Hall & Co.) in 1987, Jim served as a fire protection consultant and special representative with the Industrial Risk Insurers (IRI) - Philadelphia office.
Education:	St. Joseph's University - MS, Environmental Protection & Safety Mgmt, 2011 La Salle University - MBA, Risk Management & Insurance, 1986 Drexel University - BS, Civil Engineering, 1979
Professional Designations:	CFPS (Certified Fire Protection Specialist)
Affiliations:	NFPA (National Fire Protection Association) - Voting Member
Client Experience:	Heavy Industry Healthcare Pharmaceuticals / Chemicals Real Estate Technology