NYSERDA Case Study:

Dr. Max Zhang Environmental Research

Final Report

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NYSERDA Case Study: Dr. Max Zhang Environmental Research

Executive Summary

- Dr. K. Max Zhang is the Provost's Fellow for Public Engagement at the Cornell Atkinson Center for Sustainability. His research interests include renewable energy systems, air pollution, decarbonization, and environmental justice. Dr. Zhang's work aligns with New York State decarbonization goals under the Climate Leadership and Community Protection Act (CLCPA).
- NYSERDA's Environmental Research Program, designed to support energy policy-relevant research, has awarded Dr. Zhang approximately $2 million in funding across eight contracts. Dr. Zhang leveraged this NYSERDA funding to secure over $3 million in additional research funding.
- This case study evaluates the benefits of Dr. Zhang's NYSERDA-funded research in five energy-relevant categories: knowledge, economic, public policy, environmental, and public health. Analysis of benefits is informed mainly by stakeholder interviews.

Energy-relevant Scientific Knowledge Benefits

- Dr. Zhang has published 23 academic papers based on research funded by NYSERDA, all of which sought to improve understanding of air pollution and other effects from how we generate or use energy. As of April 2024, Dr. Zhang's NYSERDA-funded papers have been cited over 640 times, including 11 papers that have each been cited over 20 times and seven that have each been cited over 50 times.
- Dr. Zhang's work on energy and air quality is filling critical knowledge gaps. The insights from Dr. Zhang's models will help New York State determine the most efficient and robust mix of renewable energy sources throughout the year depending on weather. In addition, Dr. Zhang's work to identify more efficient methods of balancing energy supply and demand will result in lower cost electrification.

Public Policy Benefits

- Dr. Zhang's work was cited in 6 NYCRR Part 222, "Distributed Generation Sources," which established emission control requirements for sources used in demand response programs.
- His research findings on the regional and local air quality impact of peaker diesel generators contributed to New York State's regulation of diesel backup generators.
- Dr. Zhang's dual-use solar research was cited in New York State Senate Bill 7081, which aims to preserve agricultural activities and promote ecosystem services at utility-scale solar farms.
- Interview respondents emphasized that Dr. Zhang's research informs public policy discussions and understanding of policy issues in ways that are not fully captured in research citations.
- Dr. Zhang's NYSERDA-funded work has resulted in follow-on policy research funded by other New York-based and national agencies (as described more fully in this case study).

Environmental and Public Health Benefits

- Dr. Zhang created an integrated framework that brings together air quality, emissions, energy, and meteorological data. This has resulted in improved understanding of energy-related environmental and public health impacts.
- His research on homes in upstate New York that use wood stoves for heating demonstrates the public health implications of his work at a local level.
- Dr. Zhang's ongoing work to quantify the benefits of distributed generation on an area of the South Bronx that faces a high pollution burden supports the CLCPA's mandate to mitigate public health impacts of poor air quality in disadvantaged communities.

Background

Dr. K. Max Zhang (hereafter "Dr. Zhang") is the Provost's Fellow for Public Engagement at the Cornell Atkinson Center for Sustainability and the Irving Porter Church Professor of Engineering. He received his PhD in Mechanical Engineering from the University of California, Davis in 2004. His research interests include renewable energy systems, air pollution, decarbonization, and environmental justice.

Dr. Zhang's work aligns with New York State decarbonization goals to achieve zero-emission electricity levels consistent with the Climate Leadership and Community Protection Act (hereafter "CLCPA") as implemented through the New York State Energy Plan.[1] NYSERDA's Environmental Research Program, designed to support energy policy-relevant research, has awarded approximately $2 million in funding across eight contracts. Dr. Zhang leveraged NYSERDA funding to secure over $3 million in additional research funding (**Appendix A**).

Dr. Zhang disseminates knowledge on energy policy-relevant topics through peer-reviewed journals, conferences, working groups, and the Cornell Cooperative Extension network. Dr. Zhang engages with Cornell's Cooperative Extension staff and has presented to the New York State Agricultural-Technical Working Group on his solar research findings in the agriculture space.

The Environmental Research Program at NYSERDA often pairs the researcher with a multidisciplinary Project Advisory Committee (hereafter "PAC"). Dr. Zhang's PAC is comprised of scientists with expert knowledge of air quality, industry representatives, and policy experts. Members meet periodically at key decision points in the research process to provide insights and recommendations.

This case study describes the impacts of Dr. Zhang's research funded by NYSERDA's Environmental Research Program as it relates to public policy, energy generation, air quality modeling, and environmental justice, highlighting the benefits of Dr. Zhang's NYSERDA-funded research to New York State. The case study also discusses the PAC system and its effectiveness to support NYSERDA research projects.

Methodology

This case study is based on a review of NYSERDA project documents and interviews with key stakeholders, including members of the PAC, NYSERDA employees, and Dr. Zhang. Eight interviews were conducted with individuals across multiple New York State entities with expertise in energy, air quality, public health, and research, including: NYSERDA (Environmental Research Program, Science Advisory Committee, and Offshore Wind Program), Environmental Energy Alliance of New York, NYSDEC (Department of Environmental Conservation), NYISO (Independent System Operator), Con Edison, and Cornell University (Dr. Zhang).

A list of project benefits was developed in **Table 1** in consultation with NYSERDA and Dr. Zhang. Benefits are distributed across five main energy-relevant categories: knowledge, economic, public policy, environmental, and public health. Analysis of benefits is informed mainly by stakeholder interviews.

[1] Climate Leadership and Community Protection Act of 2019, Senate Bill S6599, https://legislation.nysenate.gov/pdf/bills/2019/S6599.

Table 1. Project Benefits

Category	Benefit	Beneficiaries
Knowledge	Knowledge contributions to energy/environmental research	NYSERDA, Researchers, Society
Economic	Lower cost of achieving policy goals	Society, NYSERDA
Public Policy	Policy changes - Policymakers adopt or revise policies based on information from NYSERDA-supported research	NYSERDA, Society
Environmental	Reduced GHG and criteria pollutants associated with public policy changes	Society, NYSERDA
Public Health	Increased health associated with reduced GHG and other emissions	Society

Energy-relevant Scientific Knowledge Benefits

The broader energy-relevant scientific knowledge benefits were a key theme of the interviews. Dr. Zhang has published 23 academic papers based on research funded by NYSERDA, all of which sought to improve our understanding of air pollution and other effects from how we generate or use energy. The complete list can be found in **Appendix B**, including the total citations for each publication. As of April 2024, Dr. Zhang's 23 NYSERDA-funded papers have been cited over 640 times, including 11 papers that have each been cited over 20 times and seven have been cited over 50 times each. The case study research, including interviews, shed further light on the reach and influence of Dr. Zhang's NYSERDA-funded research.

> "He breaks down really complex things and makes it easy for people to understand, even people without a science background."
>
> *- Interviewee from NYSDEC, Division of Air Resources*

Dr. Zhang's NYSERDA-funded research includes projects that investigated the summer ozone peak problem and science-based transportation green infrastructure designs.[2] A major contributor to summer peak ozone pollution is peak electricity demand for built-environment cooling during the warmest summer days. During interviews, Dr. Zhang explained that "these sources [peaking units] emit a large amount of nitrogen oxides (NOx), volatile organic compounds (VOCs), and particulate matter (PM) relative to other sources, which trigger the formation of harmful ground-level ozone pollution. In addition, the power grid is most stressed during these high peak demand periods. As a result, we have concurrent high electricity prices, high ozone pollution, high temperatures, and a stressed power grid. Further compounding this problem, a number of these peaking units are in New York City, thus affecting a large population in overburdened neighborhoods."

An emerging practice in 2014-2015 was to meet peak demand using diesel backup generators in demand response (DR) programs. These generators, however, were originally intended for emergency purposes only (i.e., blackouts) and do not usually have effective emission controls. Dr. Zhang explained that through analyzing DR program enrollment data, DR event records, air quality monitoring data, emission characteristics of the generators, previous studies (including a report by NESCAUM), and numerical simulations, his team discovered that the emissions from diesel generating units contribute to exceedingly

[2] The information in this section draws on interviews and email communication with Dr. Zhang, who provided write-ups on his work.

high ozone concentrations in the Northeast Corridor region, and very likely account for a substantial fraction of total NOx emissions from electricity generation during peak periods. His research team also discovered that emissions from diesel generators could form near-source PM hotspots, especially with the presence of tall upwind or downwind buildings. These findings contributed to policy decisions in New York State (for more information, see **Public Policy Benefits** section).

> "Max's findings of offshore wind meeting peak demand in the winter is one example of his work supporting a cost-effective energy transition. Another example is that during summer, while offshore wind production will be lower overall, production will peak at the same time of day as the peak demand for air conditioning. This allows us to develop strategies for using energy storage effectively."
>
> *- Interviewee from NYSERDA's Environmental Research Program*

Dr. Zhang's work on energy and air quality is filling critical knowledge gaps both in and outside academia because he is skilled at distilling complicated information for people without a science background. The insights from Dr. Zhang's models will help New York State determine the most efficient and healthy mix of renewable energy sources throughout the year depending on weather.

Dr. Zhang's work to identify more efficient methods of balancing energy supply and demand will result in lower cost electrification. One key example is that Dr. Zhang's model allows policymakers to test various energy solutions and compare them in advance of implementation. Some interviewees spoke to the unique insights Dr. Zhang has found on offshore wind and its ability to meet winter peak demand, thus helping to increase the number of renewable energy sources that can be used during winter.

Dr. Zhang has also brought together air quality, emissions, energy supply, and meteorological data to create models that include many components that are central to the energy transition conversation. For example, the NYSERDA project "Integrated Energy, Air Quality and Health Assessment of Clean Energy Initiatives in New York State (137485)" aims to further develop the integrated framework and evaluate the air quality and health impact of three energy initiatives: offshore wind energy, electrification of the transportation sector, and electrification of the heating sector.

> "What he did with integrating air quality and emissions of all types of energy production (combustion and renewables) and meteorology (how weather interacts with renewable production) under one big umbrella instead of three different ones was such an innovative idea."
>
> *- Interviewee from NYSERDA's Science Advisory Committee*

Dr. Zhang's air quality work has also helped to improve modeling of air flow around buildings, which impacts the air pollutant concentrations released near buildings. The pollutants can be brought to the ground by the building wake, which results in elevated ground-level concentrations. This phenomenon is known as "building downwash."[3] This work supports the CLCPA mandate to identify communities that are disproportionately harmed by poor air quality.

Importantly, Dr. Zhang's NYSERDA-funded research has had far-reaching impacts in New York State, as well as other states and at the federal level. Dr. Zhang has collaborated with researchers in other states on research projects, and the researchers who cite Dr. Zhang's work are distributed across the country.

[3] Yang, Bo, Jiajun Gu, and K. Max Zhang. "Parameterization of the building downwash and sidewash effect using a mixture model." Building and Environment 172 (2020): 106694.

Collaboration with Students and Colleagues

Interviewees emphasized Dr. Zhang's commitment to engaging with students and involving them in his work with NYSERDA. Additionally, his students have gone on to conduct their own environmental research. For example, a team of Cornell students won the Department of Energy's Solar Energy Technologies Office Bonus Prize in the 2024 EnergyTech University Prize competition. The group of students, two of whom are advised by Dr. Zhang, submitted a project entitled "Agrivoltaic Design Studio" and received a $22,000 award.[4] They created a software tool that allows developers to work with farmers to create solar projects based on the conditions of the farmland. The concept they submitted was inspired by Dr. Zhang's NYSERDA-funded work.[5] Dr. Zhang's NYSERDA-funded work on solar development and agriculture also informed New York State legislation on agricultural activities at solar farms (see **Public Policy Benefits** section). This example illustrates how Dr. Zhang's NYSERDA-funded work is relevant to practical energy policy decisions today and creates opportunities for student entrepreneurship, training, and recognition.

> "I've crossed paths with his graduate students doing applied science in the real world. Max is actually training people to bring more like-minded people to the industry. He's seeding us with brainpower! His students are first-rate, and they stick around."
>
> *- Interviewee from NYSERDA's Offshore Wind Program*

More broadly, interviewees emphasized Dr. Zhang's highly collaborative approach as a researcher in working with students, PAC members, and others outside of academia. He was described as collaborative, engaging, passionate, and affable by every interviewee. Additionally, his multi-disciplinary engineering background was a highlight for many when discussing Dr. Zhang's expertise and his perspective on energy systems. Each interviewee underscored the importance of these traits in building relationships with PAC members and his ability to foster connections with students.

PAC System

The PAC system is beneficial to researchers and policymakers. It allows the researchers to access information they would not have on their own, and it allows policymakers and industry representatives to ensure the research is relevant to their work. When PAC members can lend their thoughts to a research project, they are more invested in and trusting of the results, which translates to more sharing of the results within and outside of their organizations. Interviewees explained that their participation on the PAC gave them access to research findings earlier in the research process, and they reported sharing the research products with their teams because they trust the validity of the methods and conclusions.

> "I summarize and pass along peer-reviewed papers as they come out. I know my members read them, at least the summaries. NYSERDA puts out a quarterly blurb on their research projects that I share as well. But, the informal connections and relationships from the PAC are quite important too."
>
> *- Interviewee from Environmental Energy Alliance of New York*

[4] Dawson, Chris. "Students win DOE solar prize with Agrivoltaic Design Studio," *Cornell Chronicle*, May 6th, 2024, https://news.cornell.edu/stories/2024/05/students-win-doe-solar-prize-agrivoltaic-design-studio.

[5] Friedlander, Blaine. "Zhang helps NYS to go solar, avoid land-use conflicts," *Cornell Chronicle,* October 15th, 2020, https://news.cornell.edu/stories/2020/10/zhang-helps-nys-go-solar-avoid-land-use-conflicts.

Public Policy Benefits

> "Max does a good job of stretching the academic into the policy space and really trying to do it well. He's very proactive in trying to build knowledge around the transition to a green economy."
>
> *- Interviewee from NYSERDA's Offshore Wind Program*

Dr. Zhang's analysis has provided the scientific basis for several public policy decisions. For example, findings from Dr. Zhang's air quality research led to the approval of demand response programs in New York City in 2009. The air quality analysis showed the formation of air pollution hotspots within one mile of peaking electric generation facilities, affecting seven environmental justice communities nearby, which today would likely qualify as disadvantaged communities (DACs). An administrative law judge ordered the New York State Department of Environmental Conservation to further investigate the impacts of peaking unit emissions on environmental justice communities in New York City, and the New York State Public Service Commission approved programs to reduce peak electric demand and emissions in Consolidated Edison's New York service territory. A key justification for the approval of these programs was environmental justice concerns.

Dr. Zhang's work was also cited in 6 NYCRR Part 222, "Distributed Generation Sources,"[6] which established emission control requirements for sources used in demand response programs. Specifically, the findings from Dr. Zhang's research on the regional and local air quality impact of peaker diesel generators contributed to New York State's regulation of diesel backup generators. NYSDEC introduced the legislation related to diesel backup generators in 2019 and it was adopted in 2020.

Recently, Dr. Zhang's dual-use solar research was directly cited as a motivation in New York State Senate Bill 7081, "Establishes an agrivoltaics research program," which was signed by Governor Hochul in December 2023. The legislation aims to preserve agricultural activities and promote ecosystem services at utility-scale solar farms.

> "Max has a unique ability to understand the broad energy goals and various policy options and then to focus in on the complexity of the highly dynamic interrelated energy systems, including demand and production, and the highly dynamic meteorological and atmospheric chemistry that determine the resultant air quality… No individual study can answer all questions, but Max's work is as comprehensive as you get."
>
> *- Interviewee from NYSERDA's Environmental Research Program*

Dr. Zhang's research has also impacted the broader policy conversation through his attendance at conferences. Interviewees responded to questions about the impact of Dr. Zhang's research on public policy by focusing on his cutting-edge approaches and models, as opposed to his citations. One interviewee even said that they often do not publish the research behind a policy, and that it is often the conversations at conferences or in meetings around a paper that change people's understanding (rather than reading the paper itself). A recurring theme in the interviews was that research impacts policy in a nuanced way beyond citation numbers.

A major facet of Dr. Zhang's policy relevancy is his ability to understand how to integrate complex systems to answer important questions regarding energy policy and air quality implications. Many interviewees mentioned that Dr. Zhang has a rare skill for marrying academic interests with policy goals.

[6] 6 NYCRR Part 222, Distributed Generation Sources, 2020, https://extapps.dec.ny.gov/docs/air_pdf/siprev222.pdf

The interviews yielded insights into Dr. Zhang's policy impact beyond his NYSERDA-funded projects. He is nationally recognized for his contributions to air quality, energy, and environmental justice through his work in New York State. His NYSERDA-funded work has impacted policy and has also resulted in follow-on policy research funded by other New York-based and national entities. Examples of Dr. Zhang's policy influence based on follow-on efforts to his NYSERDA-funded work are described here to emphasize the scope of his impact.

- Dr. Zhang's research on using electric vehicles (EVs) for demand response to replace peaking units and reduce emissions from the power sector contributed to legislation passed by the New York City Council in 2013 requiring that 20% of new off-street parking in the City has the electrical capacity to support EV charging. EV charging translates to demand response because EV owners can charge their vehicles during off-peak hours in response to incentives or reminders from their electric utility.
- Dr. Zhang developed the Tompkins County New York Energy Roadmap, the first county-level climate action plan in the U.S. The Energy Roadmap was approved unanimously by the Tompkins County Legislature in 2016 and has since become a model for other counties to take climate actions.

On a national level, through a U.S. EPA-funded project, Dr. Zhang's team revealed widespread ineffective NOx emission controls in heavy-duty diesel vehicles in China.[7] This important finding led to stringent in-use emission compliance programs being adopted in China. The NOx emissions from the transportation sector in China's National Emission Inventory were revised due to the findings.

Environmental and Public Health Benefits

Environmental and human health benefits can be tracked in all of Dr. Zhang's work, which focuses largely on environmental pollutants from energy emissions that create poor air quality and the impact on DACs. Dr. Zhang's research is aimed at promoting the clean energy transition and ultimately reducing harmful emissions that negatively impact people's health.

> "Max started early and recognized the value of predicting the public health impacts of emissions so we can show the public health impacts of renewable energy. He anticipated the problem sooner than most and put together this atmospheric modeling work to solve it."
>
> *- Interviewee from NYSERDA's Offshore Wind Program*

Dr. Zhang's work (discussed above) to create an integrated framework that brings together air quality, emissions, energy, and meteorological data to evaluate the air quality and health impacts of the clean energy transition is a prime example of how environmental and public health benefits intersect in his work. As an independent consultant on NYSERDA's Science Advisory Committee observed, "What he did with integrating air quality and emissions of all types of energy production (combustion and renewables) and meteorology (how weather interacts with renewable production) under one big umbrella instead of three different ones was such an innovative idea." It is also directly relevant to energy-related policy decisions. As an interviewee from NYSDEC's Division of Air Resources observed, "In our world, we need data to justify our policies and if we don't have some of that data it

[7] Wang, Xing, Dane Westerdahl, Jingnan Hu, Ye Wu, Hang Yin, Xiaochuan Pan, and K. Max Zhang. "On-road diesel vehicle emission factors for nitrogen oxides and black carbon in two Chinese cities." Atmospheric Environment 46 (2012): ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2011.10.033.

makes it a much more difficult argument. Showing what the health impact is to implement policies is really important."

Dr. Zhang's research identifying homes in upstate New York that use wood stoves for heating demonstrates the public health implications of his work at a local level. Dr. Zhang's early work on wood smoke involved his interacting closely with community members. As an interviewee from NYSERDA's Environmental Research program recalled, "He received recognition in the form of a Cornell award for this involvement in which he identified high wood smoke plumes and engaged the homeowner to burn only seasoned wood and reduced the amount of wood smoke emitted."

Dr. Zhang's ongoing work aims to quantify the benefits of distributed generation on an area of the South Bronx that faces a high pollution burden. Members of the PAC reported that there are many regional wholesale centers for produce, flowers, and meat in this area, which use refrigerator trucks running diesel engines to refrigerate their products because the facilities themselves do not have this capacity. Dr. Zhang observed that EV charging infrastructure and the electrification of the refrigerator trucks would help address this air pollution problem. This ongoing work supports the mandate of CLCPA to mitigate public health impacts of poor air quality in DACs.

Conclusion

Dr. Zhang's research informs major policy questions surrounding electrification, renewable energy technologies, air quality and public health, and community environmental impacts. NYSERDA's investments in Dr. Zhang's work help lay the groundwork for evidence-based policy decisions, and technology and market investments.

Dr. Zhang is engaging in new research on meteorology, energy production and use, resultant emissions and air quality, and public health. He is combining and integrating modeling systems in innovative ways that are shaped by engagement with PACs to inform policy-relevant decision-making. Dr. Zhang's innovative work has resulted in improved understanding and prediction of energy-related environmental and public health effects; an innovative tool that can be applied to explore energy-related policy scenario effects; and legislation to preserve agricultural activities and promote ecosystem services at utility-scale solar farms.

Appendix A. Leveraged Funds*

Project Agreement Number	Funding from NYSERDA	Co-funding Cash & In-kind	Additional Funding
100414	$189,863	$63,288	
10601	$226,055	$75,352	$337,885 (NSF)
137485	$420,000	$140,000	
154272	$199,999	$67,001	$1.5 million (DOE)
183870	$334,353	$113,722	
32972	$125,000	$41,660	
59804	$310,240	$103,340	
63036	$275,000	$91,289	$1.5 million (NSF)
Total:	**$2,090,510**	**$620,300**	**$3.3 million**

Notes: (*) For each of Dr. Zhang's NYSERDA contracts, Cornell contributed 25% cost share based on NYSERDA's formula, $_Cornell/($_NYSERDA+$_Cornell) = 25%.

Appendix B. Published Papers (as of April 2nd, 2024)

Article Title	Year	Total Citations
Modeling near-road air quality using a computational fluid dynamics (CFD) model, CFD-VIT-RIT	2009	95
Modeling chemical evolution of nitrogen oxides near roadways	2011	68
Modeling roadside black carbon concentrations in a highway-building environment	2012	53
Coupled turbulence and aerosol dynamics modeling of vehicle exhaust plumes using the CTAG model	2012	56
Modeling multiscale aerosol dynamics and micro-environmental air quality near a large highway intersection using the CTAG model	2013	56
The near-source impacts of diesel backup generators in urban environments	2015	52
Demand response, behind-the-meter generation and air quality	2015	13
Microenvironmental air quality impact of a commercial-scale biomass heating system	2017	52
A cost-benefit analysis of a pellet boiler with electrostatic precipitator versus conventional biomass technology: A case study of an institutional boiler in Syracuse, New York	2017	14
Joint measurements of PM2.5 and light-absorptive PM in woodsmoke-dominated ambient and plume environments	2017	25
The effect of heat recovery on near-source plume dispersion of a simple cycle gas turbine	2018	4
Spatial-aware source estimation in building downwash environments	2018	3
Near-source air quality impact of a distributed natural gas combined heat and power facility	2019	18
Strategic planning for utility-scale solar photovoltaic development – Historical peak events revisited	2019	23
Parameterization of the building downwash and sidewash effect using a mixture model	2020	9
Enhancing the evaluation and interpretability of data driven air quality models	2021	25
Genetic algorithm selection of the weather research and forecasting model physics to support wind and solar energy	2022	14
An open-source representation for the New York State electric grid to support power grid and market transition studies, IEEE Transactions on Power Systems	2022	10
Ambient sampling of real-world residential wood combustion plumes	2022	4
Spatial biases revealed by LiDAR in a multiphysics WRF ensemble designed for offshore wind	2023	6
The potential for agrivoltaics to enhance solar farm cooling	2023	44
Assessment of offshore wind generation reveals its critical role in the future grid	2023	0
Predicting power plant emissions using public data and machine learning	2023	0
		Total: 644