UNIVERSITY AT ALBANY
State University of New York

Toward 100 Percent Renewable Energy in New York

The role of the atmospheric sciences in reaching the milestones in the CLCPA – an analysis by the University at Albany Weather & Climate Enterprise

Jeffrey M. Freedman, Richard Perez, Jerald A. Brotzge, and Christopher D. Thorncroft

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For more information or to reach the authors, please contact Christopher Thorncroft at cthorncroft@albany.edu or the University at Albany Office of Government & Community Relations at (518) 956-8163.

1. Executive Summary

Energy policy in New York is at a historic turning point. In June 2019, Governor Andrew Cuomo signed the Climate Leadership and Community Protection Act, one of the most aggressive pieces of legislation in the nation aimed at mitigating the impacts of climate change. The CLCPA, as it is known, codified in law a sweeping framework for the reduction of the state's greenhouse gas emissions and set New York on a course over the next two decades toward 100 percent carbon-free electricity. To meet this ambitious and necessary goal, critical research into and support for the state's renewable power infrastructure is needed. The necessary expertise will cut across disciplines – not least of which are the atmospheric sciences, which include the study and prediction of the weather that impacts virtually all sources of renewable power readily available in New York.

What follows is a summary by researchers affiliated with the University at Albany Weather & Climate Enterprise of the principal opportunities and challenges that New York faces in exploiting its renewable resources to achieve these milestones, including: 1) how much renewable generating capacity the state will truly need, 2) how to make informed decisions about siting new generation facilities, and 3) how to overcome the inherently intermittent nature of wind and solar power through better weather data and better forecast information.

New York will need to add more than 100,000 MW of wind and solar generating capacity to meet the goals in the CLCPA. It is a daunting challenge – but one our society must meet and that

UAlbany researchers believe is logistically and economically attainable through continued investment by the state, federal government and industry in the underlying research.

UAlbany's Weather & Climate Enterprise hosts the largest concentration of atmospheric, climate and environmental scientists in New York – and one of the largest in the nation. UAlbany's researchers are heavily involved in foundational research on renewables and, given their location in the state capital, are uniquely positioned to advise policymakers on reaching the milestones set forth in the CLCPA. At UAlbany, New York also has a powerful tool in the New York State Mesonet to advance this work. Designed to arm emergency managers with real-time information to better protect New Yorkers from severe weather, the Mesonet and its 24/7 weather surveillance is producing a trove of new data critical to the efficient and economical development of new renewable generating capacity on the scale envisioned by the CLCPA.

The next few years will be critical to the research necessary for New York to achieve the aspirations in the CLCPA. As a public institution, UAlbany is ready to assist the state in navigating these challenges and opportunities – and in doing so firmly establish New York not just as a leader in climate policy but as a global innovator in the clean-energy economy.

2. Introduction

Renewable energy – broadly defined as on-and offshore wind, utility-scale and distributed solar generation and hydropower – is supplying a rapidly increasing share of electricity to New York's power grid. In June 2019, New York adopted the landmark Climate Leadership and Community Protection Act, setting the state on a course toward at least 70 percent statewide renewable electric generation by 2030. This ambitious plan includes the addition of 9,000 MW of offshore wind energy by 2035 and a shift to 100 percent generation from renewable energy sources by 2040.[1] With increasing penetration of renewables on the New York electric grid, there is a an urgent need to better quantify the potential of New York's renewable resources, improve forecasting of power production on a variety of timescales (including threats to grid stability from large, short-term swings in wind and solar power generation) and more effectively assess the performance of renewable power plants. Given that utility-scale renewable-energy generation facilities (> 2 MW) – specifically onshore wind and solar power – are now cheaper to build than fossil fuel plants (Teplin et al. 2019), the CLCPA and a favorable financial climate will further accelerate the growth of renewable energy generation across New York.

The State of New York currently generates 29 percent of its electricity from renewable energy sources. While more than 80 percent (about 6,000 MW) of this generation is from hydropower (Figure 1), nearly all new development to meet the state's 100 percent renewable energy goal will come from wind and solar power.[2] Federal regulations require New York to maintain approximately 38,000 MW (New York Independent System Operator 2019) of generating capacity.[3] Meeting this generation threshold through renewables, however, is not simply a matter of incorporating an additional 30,000 MW of wind and solar energy into the generation mix. Electric power generation is dependent upon a local source's *capacity factor*.

[1] The New York State Legislature passed and the Governor signed into law the CLCPA on 20 June 2019. See ECL §§75-0101 - 75-0119.
[2] It is unlikely, given environmental considerations, that significant additions to New York's nearly 6,000 MW of hydropower generation are feasible. Most additional hydropower generation will likely come from enhancing existing generation facilities.
[3] For 2019-2020, the Federal Energy Regulatory Commission established that New York requires 17% reserve capacity based upon a predicted maximum load of 32,000 MW.

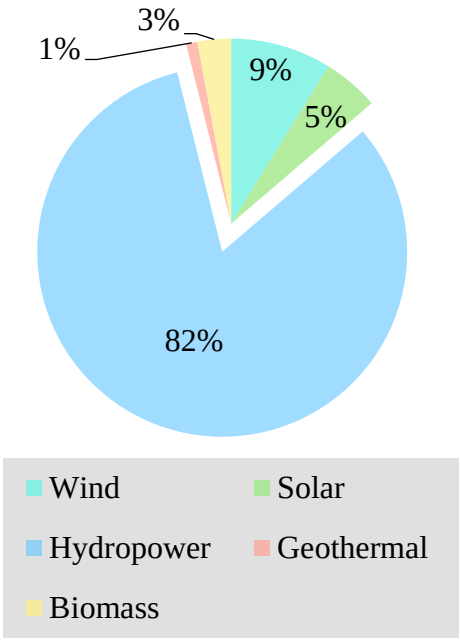

Figure 1. Renewable energy generation (2018) in New York State. Sources: NYSERDA and USEIA.

The capacity factor is the average annual generation divided by the *nameplate capacity* – that is, the rated generation for a wind turbine or solar photovoltaic (PV) cell. Onshore wind farms have a typical capacity factor of 35 percent; offshore, where the wind is more persistent, capacity factors are 45 percent or higher. For solar PV, capacity factors are generally between 15 and 20 percent.[4] A facility's capacity factor is therefore determinative of the actual generation required to meet New York's current and future energy needs. **Thus, to ensure a reliable supply of power sourced 100 percent through renewables, New York will need to add more than 100,000 MW of additional wind and solar energy to the grid.** This, in turn, will require more detailed, higher resolution weather and climate observations to support resource assessment, more accurate model forecasts to reduce uncertainty given the inherent variability of wind and solar power, and the scientific knowledge to develop better tools to provide cost-effective deployment of a vast network of renewable energy generating facilities. Given these challenges, the University at Albany's Atmospheric Sciences Research Center (ASRC), Center of Excellence in Weather & Climate Analytics (COE) and New York State Mesonet are uniquely positioned to facilitate the rapid integration of renewables into New York's power grid.[5] Collectively, these entities are known as the UAlbany Weather & Climate Enterprise.

[4] For hydropower, capacity factors are typically 70-90 percent. Non-renewable generation, such as combined-cycle gas turbines and nuclear power, generally have capacity factors around 80% or higher.
[5] Formerly known as the Center of Excellence in Atmospheric and Environmental Prediction and Innovation, the Center of Excellence in Weather & Climate Analytics is funded annually through Empire State Development's Division of Science, Technology and Innovation (NYSTAR).

3. UAlbany and the Atmospheric Sciences Research Center

Atmospheric sciences and renewable energy are major research strengths and strategic priorities for UAlbany. Established in 1961, the Atmospheric Sciences Research Center is internationally recognized for its scholarship in atmospheric sciences and decades-long leadership in integrating the very same climate, weather and energy issues that society more broadly is confronting today. ASRC currently supports 15 full-time research faculty, 17 full-time support staff and more than 20 graduate students and post-doctoral fellows. Together with the UAlbany Department of Atmospheric and Environmental Sciences and the other entities described below, the UAlbany Weather & Climate Enterprise supports more than 120 faculty, graduate students, post-doctoral research and support staff – one of the largest groups focused on weather and climate research in the United States.

In 2012, Governor Cuomo approved UAlbany's NYSUNY 2020 strategic investment plan to, among other things, 1) build the largest atmospheric sciences program in the state and 2) construct ETEC, a $180 million state-of-the-art research and development facility that in 2021 will become the home of the UAlbany Weather & Climate Enterprise as well as the College of Emergency Preparedness, Homeland Security and Cybersecurity. Two years later, Governor Cuomo selected UAlbany to build the $30 million New York State Mesonet (NYSM), the nation's gold standard for early-warning weather observation systems. While the Mesonet was built to protect New Yorkers from severe weather, a byproduct of the network's 24/7 weather surveillance is a trove of new data invaluable to the efficient and economical development of new renewable generating capacity. All this data is processed and quality controlled at UAlbany.

In 2015 and 2016, the state made additional investments in the UAlbany Weather & Climate Enterprise, funding a Calibration Laboratory, the xCITE Visual Analytics and Machine Learning Lab and the New York State Center of Excellence in Weather & Climate Analytics. At the same time, UAlbany researchers won two prestigious National Science Foundation (NSF) Partnership in International Research and Education awards totaling $9.5 million.

The Renewable Energy Group at ASRC led by Richard Perez, Jeffrey M. Freedman, and Qilong Min has international expertise and decades of experience in resource assessment, forecasting, system integration and development of state-of-the-art measurement systems.

Research sponsors include the NSF, the National Oceanic and Atmospheric Administration (NOAA), the New York State Energy Research and Development Authority (NYSERDA), the U.S. Department of Energy, the National Aeronautical and Space Administration (NASA), and private sector partners such as Clean Power Research, MESO Inc., and UL-Renewables.

4. The New York State Mesonet

In response to back-to-back, multi-billion-dollar weather disasters in Hurricane Irene (2011) and Hurricane/Post-Tropical Cyclone Sandy (2012), New York invested $30 million of Federal Emergency Management Agency Hazard Mitigation Grant Program funding to establish the New York State Mesonet (NYSM) (Brotzge et al. 2018). The NYSM consists of 180 state-of-the-art environmental monitoring stations (Figure 2), including 126 standard sites (spaced ~ 25 km apart) and measuring a suite of variables including temperature, moisture, precipitation, wind, solar radiation, and snow depth; 17 profiler sites consisting of wind Doppler LiDAR and profiling microwave radiometers; 17 flux sites measuring heat, moisture, momentum fluxes and the surface energy budget; and 20 snow sites measuring the liquid water content within the snowpack. Utilizing both in-situ and remote-sensed observation, the NYSM records 4D high-resolution, real-time observations that provide a detailed depiction of the ongoing weather and long-term climate of New York. The NYSM profiler sites are of particular value for renewable resource assessment, forecasting and evaluation of power plant performance, as these provide the only continuous, long-term wind-turbine hub-height observations in the state. Hub-height observations are critical to wind resource assessment because they provide information about conditions at the height of a turbine's rotor. While there are no NYSM sites offshore, the coastal LiDAR subnetwork of six sites (Figure 2) will be valuable when coupled with buoy-based LiDAR measurements being used in offshore resource assessment studies, providing information pertaining to sea breezes and offshore flow regimes. In addition, all 126 standard NYSM sites are equipped with solar monitoring sensors, providing the solar energy industry, utilities and the New York Independent System Operator (NYISO) with real-time solar observations that facilitate more efficient grid management and more cost-effective mitigation strategies. Furthermore, NYSM observations are assimilated into national weather forecast models, thereby

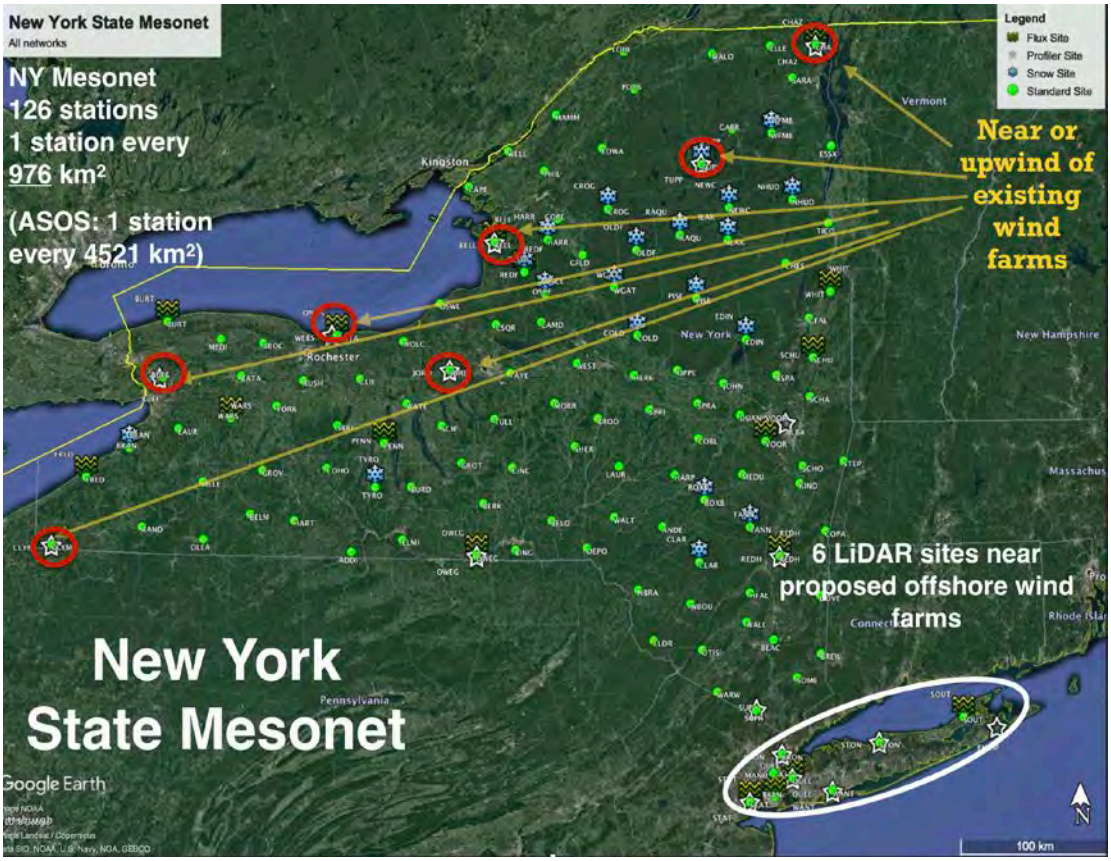

Figure 2. The New York State Mesonet. Red circles denote profiler sites upwind of utility-scale wind farms; the white oval shows coastal profiler sites that will support offshore wind farm development.

raising the reliability and accuracy of critical prediction tools across New York and the nation. The NYSM is a critical foundation to effectively monitor and predict the impacts of weather upon renewable energy production and distribution and is essential to achieving the statewide goal of 100% power generation from renewables by 2040.

5. ASRC and Renewable Energy Integration into the New York Grid

The siting and operation of renewable energy facilities depends on accurate, representative measurements and power-production forecasts that are used to predict short-term output (minutes to days) as well as cumulative future power generation over the next 20-25 years. This work includes quantifying meteorological uncertainties that are key to understanding the financial

("bankability") risks associated with siting utility-scale and distributed generation facilities. ASRC has been and continues to be at the forefront of developing improved methods for more accurately depicting and forecasting the solar and wind energy resource. During the last 20 years, the ASRC Renewable Energy Group has led the way in developing 1) globally recognized models for solar plant design, solar resource remote sensing, solar variability characterization and solar forecasts (Perez et al. 2015; Perez et al. 2019b); 2) large-scale field and modeling research projects resulting in significant improvements to the accuracy of wind energy forecasts (Freedman et al. 2014; Wilczak et al. 2015); and 3) designing and deploying the environmental Sky Imager-Radiometer (eSIR, developed by Dr. Min), which provides continuous daytime observations of aerosol and cloud optical depth, narrowband spectral direct and diffuse radiation and whole-sky images of cloud distribution and motion. In short, ASRC faculty have been and continue to be actively involved in foundational research essential to the development of New York's renewable energy portfolio.

Solar: Solar energy is the largest renewable resource on the planet. This is true even in New York despite its relatively modest solar resource compared to the Sunbelt. For example, deploying 100 GW of PV would require less than 1 percent of the state's surface area (more than half of PV installed in New York is on existing rooftops). Solar electric technologies' costs keep reaching new lows; in some places, PV is now the cheapest means to generate electricity.

The last remaining barrier facing solar (and wind) is the resource's *intermittency*. Electricity generated by both wind and solar is dependent on the weather and the cycle of days and seasons. This is unlike conventional fossil fuel and nuclear resources that can be dispatched – that is, provided on demand – and produce a guaranteed baseload output. As a result, the major challenge presented by a widespread shift toward renewables is the transformation of intermittent generation into firm, effectively dispatchable renewable electricity that can readily and economically displace conventional, polluting sources of power.

Through recent research and publications, ASRC and its collaborating institutions and businesses have demonstrated that the conversion to firm, renewable power generation is not only achievable but will also lead to ultra-high penetration of renewable electricity that is less costly than the current, carbon-based generation – even if one does not account for fossil fuels'

environmental costs and liabilities (Perez et al. 2019a; Perez and Rabago 2019). This body of work delineates actionable blueprints that can support the state's 100 percent renewable power generation goal. These investigations and their prospective application are facilitated by ASRC's internal investigative resources: remote sensing-models to produce very-high-resolution solar resource data and state-of-the-art solar forecasts.

The ASRC team is currently exploring the application of these resources to produce "perfect operational solar forecasts" by managing solar plants with shock-absorbing battery hardware and controls. In solar energy production, the term "perfect forecast" refers not simply to the weather but a condition in which a generation facility's forecasted output matches its actual output. Imperfect forecasts lead to inefficiency, with grid operators having to manage solar energy generation excesses or deficits depending on variations in demand. By contrast, perfect forecasts eliminate the prediction uncertainty associated with solar generation through the use of modest, optimized battery storage and the ability to curtail, or dump, excess power produced but not needed to meet demand. Most important for New York, refining the storage and curtailment concepts and capabilities that underpin "perfect forecasts" represents an important initial step – subsequently combined with a strategic overbuilding of the state's renewable energy generation capacity – that will enable the low-cost, reliable renewable power generation at the scale needed to power New York (Perez et al. 2019b).

Wind: With wind now poised to become a major source of power in New York, its inherent variability combined with system loads drawing more power from wind requires further improvements in monitoring and forecasting, especially on the short (0-6 hour) time scales critical for system reliability and economic dispatch. This is a priority for the New York Independent System Operator and utilities, as the uncertainty of variable generation forecasts remains a challenge (Makarov et al. 2010; Orwig et al. 2015; Kozak et al. 2019). The ability to accept wind power into electric power transmission systems is dependent upon calculations using atmospheric observations and wind forecasts. NYISO has established rules, charges, and penalties on wind energy suppliers for inaccurate energy generation projections. Substantial savings in annual system production costs can be achieved with more accurate wind forecasting (Cardell and Anderson, 2009; Freedman et al. 2014; Hou et al. 2018), ultimately resulting in

significant cost savings to ratepayers. Recent field campaigns, including one led by Dr. Freedman, have demonstrated the value of enhanced observation networks (including wind profilers and LiDAR) in improving wind power forecasts (Freedman et al. 2014; Wilczak et al. 2015). Thus, assimilating the NYSM's dense network of 126 standard sites and 17 LiDAR-equipped profiler sites offers the state, industry and New York ratepayers the opportunity to realize substantial savings through improved wind energy forecasts.

Hydropower: New York is the largest producer of hydropower east of the Mississippi River and third-largest in the nation. At present, hydropower, including pumped storage, provides 17 percent of New York's electrical needs. It is the dominant source of renewable energy in the state, with an operating capacity of 6,000 MW. Much of that generation is at two large plants near the Canadian border: the New York Power Authority's Niagara and St. Lawrence Power Projects. NYPA also owns the 1,100 MW pumped storage facility at the Gilboa Dam in the Catskills. In addition to these large-scale facilities, more than 300 smaller hydroelectric generating stations (mostly small dams) are connected to New York's electric grid. Although it is unlikely that any new, large-scale hydropower generation will be built, existing facilities will continue to be re-powered and retrofitted, leading to some additional generating capacity.

Nearly all hydropower generation in New York is located on streams and rivers whose flow is dependent upon rain and snow falling within their watersheds. Thus, accurate observations of precipitation (now provided more accurately, faster and with greater resolution by the NYSM) are crucial to determining current power production (i.e., streamflow) and estimating future production to inform financing decisions for re-powering and retrofitting projects.

ASRC and the NYSM are working with water managers such as NYPA in facilitating the use of NYSM network data, including precipitation and snowpack monitoring for hydrological forecasting. As hydropower will continue to play a key role in New York's advance toward 100 percent generation from renewables, ASRC and the NYSM will be able to support the state's goals in maintaining its hydropower facilities and in providing critical information for merchant

operators of the wind, solar, and hydropower generation stations in New York.[6]

6. Next Steps

The next several years will be critical for the research necessary to achieve New York's ambitious goals for renewable energy. As a public institution, UAlbany and its Weather & Climate Enterprise is ready to assist policymakers in quantifying the potential of New York's renewable resources, improving the power production forecasts that help transform that potential into generation, and assessing the performance of renewable power plants. UAlbany, and ASRC specifically, has a long history of leading research in support of the state's legislative and regulatory goals for the environment, the well-being of New Yorkers and the development of public-private partnerships in the renewable energy sector. ASRC's reputation as a world-class center for atmospheric and renewable energy research combined with critical assets such as the NYSM and the Center of Excellence in Weather & Climate Analytics frame a critical scientific role for UAlbany to play as New York moves toward carbon-free electricity. More than that, the close collaboration between UAlbany's Weather & Climate Enterprise and the private sector will allow the state to capitalize on its renewable energy goals to firmly establish New York not just as a leader in climate policy but as a global innovator in the clean-energy economy.

About the University at Albany:

A comprehensive public research university, the University at Albany-SUNY offers more than 120 undergraduate majors and minors and 125 master's, doctoral, and graduate certificate programs. UAlbany is a leader among all New York State colleges and universities in such diverse fields as atmospheric and environmental sciences, business, public health, health sciences, criminal justice, emergency preparedness, engineering and applied sciences, informatics, public administration, social welfare, and sociology taught by an extensive roster of faculty experts. It also offers expanded academic and research opportunities for students through an affiliation with Albany Law School. With a curriculum enhanced by 600 study-abroad opportunities, UAlbany launches great careers.

[6] Merchant operators are independent power producers who sell power on the spot market without long-term power purchase agreements with utilities or municipalities.

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