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STATE OF THE SCIENCE

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I. INTRODUCTION

Due to changing climate patterns, historic trends are no longer a good predictor of future conditions.[2] As a result, electric utilities must use forward-looking projections developed using climate models to properly evaluate and plan for climate-related risks. The projections used should be downscaled to reflect future conditions in the relevant utility's operating area (often referred to as the utility's "service territory"). Downscaled climate projections suitable for use by electric utilities have been published by various government, academic, and independent bodies.[3]

II. GLOBAL CLIMATE MODELING AND DOWNSCALING

Future climate conditions can be projected using global climate models ("GCMs") that simulate various components of the earth's climate system (i.e., atmosphere, land surface, ocean, and sea ice).[4] GCMs enable scientists to understand how changes in atmospheric greenhouse gas concentrations will affect climate variables (e.g., temperature).[5]

Most GCMs use grid cells that extend sixty miles or more on one side, resulting in coarse-resolution projections that cover large geographic areas.[6] Even the latest models, which use grid cells of fifteen to thirty miles, may generate projections that are too coarse for use by electric utilities in climate resilience planning.[7] However, using downscaling techniques, scientists can refine projections generated by GCMs to estimate climate impacts at finer geographic scales.[8] There are two main approaches to downscaling—the first approach is dynamical downscaling, which utilizes regional climate models ("RCMs") to directly simulate responses of regional climate processes to global change, while the second approach, referred to as empirical statistical downscaling, utilizes

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[1] This document is part of the electric resilience toolkit, https://www.icrrl.org/electric-resilience-toolkit/, and complements sections one through three of the law review article, Romany M. Webb et al., Climate Risk in the Electricity Sector: Legal Obligations to Advance Climate Resilience Planning by Electric Utilities, 51 Envtl. L. Rev. 577 (2021). The authors would like to thank Jeffrey Fralick, Climate Risk Analyst at Environmental Defense Fund, for his assistance in preparing this document. Disclaimer: This document is the responsibility of the Sabin Center for Climate Change Law and Environmental Defense Fund, and does not reflect the views of Columbia Law School, Columbia University, or any ICRRL partner organization. This document is an academic study provided for informational purposes only and does not constitute legal advice. Transmission of the information is not intended to create, and the receipt does not constitute, an attorney-client relationship between sender and receiver. No party should act or rely on any information contained in this paper without first seeking the advice of an attorney.
[2] *See* U.S. DEP'T OF ENERGY, A REVIEW OF CLIMATE CHANGE VULNERABILITY ASSESSMENTS: CURRENT PRACTICES AND LESSONS LEARNED FROM DOE'S PARTNERSHIP FOR ENERGY SECTOR CLIMATE RESILIENCE 12 (2016), https://perma.cc/5EKK-T9GA [hereinafter 2016 DOE Partnership Report].
[3] *See* notes 12–18, *infra*, and accompanying text.
[4] *See* Hayhoe et al., *Climate Models, Scenarios, and Projections, in* CLIMATE SCIENCE SPECIAL REPORT: FOURTH NATIONAL CLIMATE ASSESSMENT, VOLUME I 141 (D.J. Wuebbles et al., 2017), https://perma.cc/HB9P-F8EL.
[5] *Id*.
[6] *See* CONSOLIDATED EDISON, CLIMATE CHANGE VULNERABILITY STUDY 17 (Dec. 2019), https://perma.cc/AT9S-2VAV.
[7] *See* Hayhoe et al., *supra* note 4, at 141; Romany M. Webb et al., *Climate Risk in the Electricity Sector: Legal Obligations to Advance Climate Resilience Planning by Electric Utilities*, 51 ENVTL. L. REV. 577, 586–87 (2021), https://perma.cc/WV5Y-U2HL.
[8] *See* Hayhoe et al., *supra* note 4, at 144, 145.

statistical relationships to infer local climate information from large-scale climate information that has been produced by GCMs.[9] Using these techniques, scientists can produce highly granular climate projections, in some cases with spatial scales below 2.5 miles, and even as fine as 0.6 miles.[10] Probability distributions can be attached to downscaled projections to enable an assessment of the relative likelihood of different climate outcomes.[11]

Downscaled projections have been published by various government, academic, and independent bodies. For example:

- The U.S. Department of Energy has partnered with the National Aeronautics and Space Administration and National Oceanic and Atmospheric Administration to make available zip code-level temperature projections and county-level precipitation and sea level rise projections in formats that can be readily inputted into models and other systems used in utility planning.[12]
- The U.S. Geological Survey has partnered with the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University to develop a "Regional Climate Change Viewer" that includes downscaled projects for over 60 climate variables, including air temperature and precipitation.[13]
- The U.S. Bureau of Reclamation has partnered with multiple universities and non-governmental organizations to develop downscaled projections for climate change impacts on hydrology, ecosystems, and energy demands across the U.S.[14]
- The University of California Berkeley, with support from the California Energy Commission and California Strategic Growth Council, has developed the Cal-Adapt tool, which provides projections for average annual maximum and minimum temperatures, precipitation and drought, extreme weather, wildfire and sea level rise in California under two climate change scenarios.[15] The projections show future conditions at 3.5 square mile increments.[16]
- The New York City Panel on Climate Change and New York State Energy Research and Development Authority have published downscaled projections for key climate parameters in New York.[17]
- Projections for many other regions are available in academic publications and commercial databases.[18]

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[9] *See id.*
[10] *Id.* at 144.
[11] Webb et al, *supra* note 7, at 586–87.
[12] *See Energy Data Gallery*, U.S. Climate Resilience Toolkit, https://toolkit.climate.gov/topics/energy/energy-data-gallery (last updated Sept. 24, 2019).
[13] *Regional Climate Change Viewer*, U.S. Geological Surv., http://regclim.coas.oregonstate.edu/visualization/rccv/index.html (last visited April 29, 2022).
[14] U.S. Bureau of Reclamation et al., *Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections*, https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/#Welcome (last visited April 29, 2022).
[15] *About Cal-Adapt*, Cal-Adapt, https://cal-adapt.org/about/ (last visited April 29, 2022); *Climate Tools*, Cal-Adapt, https://cal-adapt.org/tools/ (last visited April 29, 2022).
[16] *See Climate Tools*, Cal-Adapt, https://cal-adapt.org/tools/ (last visited April 29, 2022); *Get Started*, Cal-Adapt https://cal-adapt.org/help/get-started/climate-data-and-other-data-on-caladapt (last visited April 29, 2022);
[17] Radley Horton et al., *Climate Change Adaptation in New York City: Building a Risk Management Response, Chapter 3: Climate observations and projections,* 1196 ANN. N.Y. ACAD. SCI. 41 (2010), https://nyaspubs.onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2009.05314.x; N.Y.C. Panel On Climate Change, Climate Risk Information 2013: Observations, Climate Change Projections, and Maps (2013), https://perma.cc/YX5L-7UDK; Radley Horton et al., *New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections*, 1336 ANN. N.Y. ACAD. SCI. 18 (2015), https://nyaspubs.onlinelibrary.wiley.com/doi/10.1111/nyas.12586; Jorge F. Gonzalez et al., *New York City Panel on Climate Change 2019 Report, Chapter 2: New Methods for Assessing Extreme Temperature, Heavy Downpours, and Drought*, 1439 Ann. N.Y. Acad. Sci. 30 (2019), https://nyaspubs.onlinelibrary.wiley.com/doi/10.1111/nyas.14007.
[18] *See, e.g.*, Liang Ning, *Probabilistic Projections of Climate Change for the Mid-Atlantic Region of the United States: Validation of Precipitation Downscaling during the Historical Era*, 25 J. Climate 509 (2012); Four Twenty Seven, Physical Climate Risk Application (2020), https://perma.cc/V5ZM- 37XL

As these examples indicate, climate projections suitable for use by electric utilities are now available from a number of sources. In some cases, however, utilities may need custom projections.[19] Recent advances in modeling techniques have made it easier for electric utilities to obtain custom projections.

While downscaled projections can provide valuable information about likely future climate conditions in an electric utility's service territory, and thus assist the utility to evaluate its climate-related risks, their use can present challenges. The projections generated by climate models are inherently uncertain because, despite recent advances, scientists still have incomplete understanding of the Earth's climate system and must make assumptions about key model inputs, such as future greenhouse gas emissions.[20] Scientists can assess how well a model functions by comparing its projections to observational data but cannot completely eliminate all sources of uncertainty. As a result, model projections are typically conveyed in terms of degrees of confidence, rather than absolute certainty. That does not, however, render the projections useless. Electric utilities have, in the past, successfully used climate projections to inform their assessment of future risks to their assets and operations. One example is discussed in Part III below.

III. Consolidated Edison Climate Study

Consolidated Edison Company of New York, Inc. ("Con Ed") partnered with scientists within ICF's climate adaptation and resilience team, along with researchers at Columbia University's Lamont-Doherty Earth Observatory, to develop downscaled climate projections specific to its service territory.[21] Projections were generated for temperature, humidity, precipitation, sea level, and extreme weather during seven time periods spanning from 2020 through 2080.[22] While modeling was only able to produce climate projections at fairly high resolution, with grid cells extending 100 kilometers, scientists used historical data from several weather stations in Con Ed's service territory to adjust the simulations to bring them closer to observed data, and provide more granular local climate projections for the New York City area.[23] Con Ed used those projections to assess potential risks to its assets and operations and published the results of that assessment its Climate Change Vulnerability Study (see *Climate Resilience Planning Process*). Con Ed's experience demonstrates that it is possible for electric utilities to draw on current climate data and tools to conduct vulnerability and resilience assessments.

[19] *See* U.S. Dep't of Energy, Climate Change & the Electricity Sector: Guide for Climate Change Resilience Planning 25 (2016), https://perma.cc/29MD-XWEE;

[20] *See generally* Primavera, Uncertainty in Climate Projections (2020), https://perma.cc/987N-QJP6.

[21] Consolidated Edison, Climate Change Vulnerability Study, supra note 6, at 11, 17 n.5.

[22] *Id.* at 17–18.

[23] *Id.* at 17.