

Vignesh Venugopal

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ENERGY AND ENVIRONMENTAL ECONOMICS, INC.

Managing Consultant

New York, NY

Vignesh joined E3 in 2019 and manages long-term resource planning projects for clients in the electricity industry. He has employed E3's load forecasting, capacity expansion and loss-of-load probability models, for organizations working towards cost-effective decarbonization without compromising reliability. His areas of expertise include emerging resources like energy storage, demand response, hydrogen and CCS. He has worked for a wide range of clients interested in emerging resources in different parts of North America. For example, he was involved in the 2022 Storage Roadmap development for New York, 2023 IRP development for Manitoba Hydro, which included modeling of emerging resources, and a Demand Response ELCC Study for the California ISO completed in 2021. Vignesh came to E3 after completing his master's degree in Energy Resources Engineering from Stanford University. His research was focused on distributed solar PV output forecasting using machine learning (ML). He applied ML and optimization to improve forecasting for distributed solar systems and assess the cost impacts of improved forecasting on system dispatch.

Select projects at E3 include:

- **NY 2022 Storage Roadmap, New York State Energy Research and Development Authority (Jan 2022- Dec 2022)**¹ - Conducted analysis and drafted a roadmap for NY state to meet their 6 GW by 2030 target in collaboration with NYSERDA and the New York State Department of Public Service. In addition to the pathway charted for NY to meet the 2030 target, E3 also assessed the role short and long duration storage can play in the long term to make net-zero goals cost effective.
- **Integrated Resource Plan Support Including Consideration of Emerging Resources (Multiple electric utilities)** – Modeling and/or advisory support for IRP development, regulatory filings, and stakeholder engagement. Clients include but are not limited to Tucson Electric Power, Manitoba Hydro² and Omaha Public Power District. Deep decarbonization scenarios modeled included input development and modeling of emerging resources.
- **Effective Load Carrying Capability of Demand Response, California Independent System Operator (Nov 2019-June 2021)**³ - Determined the ELCC (i.e capacity value) of existing demand response (DR) programs and guided future DR program valuation and design. Led the RECAP analysis and participated in a working group led by the CEC to update the resource adequacy framework in CA to accurately value distributed energy resources like DR.

¹ <https://www.nysERDA.ny.gov/-/media/Project/Nyserda/Files/Programs/Energy-Storage/ny-6-gw-energy-storage-roadmap.pdf>

² <https://www.hydro.mb.ca/docs/corporate/irp/irp-2023-integrated-resource-plan.pdf>

³ <https://www.caiso.com/Documents/Presentation-ELCCStudyResults-DemandResponseResources-Jun24-2021.pdf>

- **Resource Planning for NY to meet the Climate Leadership and Community Protection Act goals, NYSERDA (Oct 2020- Present)⁴** - Used RESOLVE to evaluate supply options cost optimally for different scenarios all of which attain 100% zero-carbon electricity by 2040 as part of the CLCPA goals. Used RECAP to determine the capacity value of variable and energy-limited resources. The study includes consideration of technologies like green hydrogen, long duration battery storage, offshore wind, negative emission technologies, etc.
- **CCS Feasibility in the US, Confidential Client (Jun 2023 – Aug 2023)** – Conducted market research and assessed the feasibility of retrofitting existing natural gas plants or building new gas plants with carbon capture and storage as part of a diverse resource portfolio that also includes solar, wind and battery storage, to help reliably meet demand with zero-carbon resources when solar and wind underperform. Both general and location-specific environmental and PR risks associated with CCS were considered in the study.
- **Evaluating the Need for Hydrogen Pipeline Infrastructure, Confidential Client (Nov 2023 – Present)** –Assessment of existing and future hydrogen demand, infrastructure, and policy considerations to evaluate the need for pipelines in a part of US of interest to the client.
- **Assessing the Value of Long Duration Energy Storage, California Energy Commission (Apr 2020- Jun 2021)** - Used RESOLVE and RECAP to assess the role LDES can play in meeting CA’s decarbonization goals while maintaining reliability when renewable energy output is not enough.
- **Hydrogen Pathways in WECC, Mitsubishi Power (Dec 2019-Feb 2020)⁵** - Developed cost projections for producing hydrogen from different energy sources and electrolyzer technologies through 2050.
- **Testimonies (Multiple clients)** – Reviewing utility IRPs and filing testimonies on behalf of clean energy stakeholders, trade associations such as the Carolinas Clean Energy Business Association and the Georgia Large Scale Solar Association. Testimony reviewing Bonneville Power Administration’s Provider of Choice Policy on behalf of Seattle City Light.
- **Impact of Climate Change on Electricity Systems (Confidential Client) (Sep 2022 – Present)** – Quantifying impact of warming on electricity demand, resource outages, transmission derates, etc. The study is also speaking to the differences in impacts expected based on the decarbonization policies adopted.
- **Predicting Operating Reserve Needs Using Machine Learning, Advanced Research Projects Agency–Energy (Oct 2020-Dec 2021)⁶** - Developed a machine learning model, RESERVE, for predicting operating reserve requirements given solar, wind and load forecasts. The model produces probabilistic forecasts to accurately capture uncertainty and support efficient grid operations with reduced costs and emissions.
- **Net-zero New England, Calpine Corporation (Mar 2020-Nov 2020)⁷** - The study charted pathways for New England to attain net-zero emissions, economy-wide by 2050. Led the RECAP

⁴ <https://climate.ny.gov/resources/scoping-plan/>

⁵ https://www.ethree.com/wp-content/uploads/2020/07/E3_MHPS_Hydrogen-in-the-West-Report_Final_June2020.pdf

⁶ <https://pubs.aip.org/aip/jrse/article/14/3/036303/2845529/Machine-learning-derived-dynamic-operating-reserve>

⁷ https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_November_2020.pdf

modeling to determine the ELCC of different resources and stress-test the New England system under challenging conditions to ensure reliability. Highlighted the value of zero-carbon firm resources in periods with high load and low renewable generation

STANFORD UNIVERSITY

Teaching Assistant

Stanford, CA
January 2019 – March 2019

- Held weekly office hours to help students with course content, weekly assignments, and projects for *ENERGY 191/291: Optimization of Energy Systems*
- Aided both the theoretical understanding of optimization and its practical implementation in the Julia for Mathematical Programming (JuMP) framework

STANFORD UNIVERSITY

Research Assistant, Environmental Assessment and Optimization Group

Stanford, CA
September 2017 – June 2019

- Researched short-term solar panel output forecasting with machine learning
- Employed Convolutional Neural Networks for predictions using sky images
- Investigated merit of multi-modal input architectures used in the field of robotics to make use of images, PV output history and weather parameters for improving accuracy
- Supplementary projects included stochastic unit commitment modeling and market research to quantify the costs and benefits of a better solar forecast

UNIVERSITY OF MUMBAI

Undergraduate Researcher, Department of Chemical Engineering

Mumbai, India
August 2016 – March 2017

- Researched biodiesel production from used cooking oil to avoid “food vs. fuel” debates
- Experimented with microreactors to induce slug flow, increase interfacial area and thus the rate of reaction without the need for agitation or co-solvents

JACOBS ENGINEERING INDIA PVT LTD

Intern, Department of Process Engineering

Mumbai, India
June 2016 – July 2016

- Re-engineered a batch operating plant producing food flavorings and performance chemicals into continuous production mode

BHABHA ATOMIC RESEARCH CENTER

Intern, Department of Health Physics

Mumbai, India
June 2015 – July 2015

- Collected environmental samples and conducted radiation detection and measurement of H3 and C14 levels in those samples using a Liquid Scintillation Counter

Education

Stanford University
M.S., Energy Resources Engineering

Stanford, CA
June 2019

Peer-Reviewed Publications

- Yuchi Sun, James H. Nelson, John C. Stevens, Adrian H. Au, Vignesh Venugopal, Charles Gulian, Saamrat Kasina, Patrick O'Neill, Mengyao Yuan, Arne Olson (2022); Machine learning derived dynamic operating reserve requirements in high-renewable power systems. *Journal of Renewable and Sustainable Energy*; 14 (3): 036303.
- Venugopal, V., Sun, Y., & Brandt, A. R. (2019). Short-term solar PV forecasting using computer vision: The search for optimal CNN architectures for incorporating sky images and PV generation history. *Journal of Renewable and Sustainable Energy*, 11(6), 066102.
- Sun, Y., Venugopal, V., & Brandt, A. R. (2019). Short-term solar power forecast with deep learning: Exploring optimal input and output configuration. *Solar Energy*, 188, 730-741.