



44 Montgomery Street, Suite 1500, San Francisco, CA 94104
zachary.ming@ethree.com

ENERGY AND ENVIRONMENTAL ECONOMICS, INC.
Senior Director

San Francisco, CA

Mr. Ming is a Director in E3's market design practice, with an emphasis on electricity systems operating under higher penetrations of renewable energy. He also has extensive expertise in resource planning, reliability and resource adequacy, regulatory and rate design issues, and distributed resource cost effectiveness. Recent projects include advising the Public Utility Commission of Texas on market reforms to improve reliability and studying pathways to net-zero carbon in Nebraska. Mr. Ming has been the lead author on several high-profile resource planning studies including *Long-Run Resource Adequacy under Deep Decarbonization Pathways for California*¹ and *Resource Adequacy in the Pacific Northwest*.²

Mr. Ming teaches a graduate level course at Stanford University titled *Electricity Economics* that provides a foundation of economic principles on the topics of regulation, planning, and operation of electric utilities, with a particular emphasis on emerging electricity sector topics such as renewable energy, energy storage, distributed resources, and market design.

Mr. Ming holds an M.S. in management science and engineering (energy and environment track) and a B.S. in civil and environmental engineering (atmosphere and energy) from Stanford University. Select projects at E3 include:

- **Market Design Reform Analysis, Public Utility Commission of Texas, 2022-2023:** Mr. Ming led analysis to evaluate the portfolio, reliability, and cost impacts of various market design reform proposals being contemplated in the ERCOT market. E3 published these findings in a report, and Mr. Ming publicly presented these results before the Commissioners at an open meeting and to state legislators.³
- **Capacity Value, Oregon Public Utility Commission, 2020-2022:** Mr. Ming developed a best practices framework for assessing the capacity value of for use in various Commission proceedings. Mr. Ming publicly testified before Commissioners at an open meeting to present results and answer questions.
- **Santee Cooper, the State of South Carolina, 2019-2020:** Mr. Ming managed an engagement with the State of South Carolina to advise on the potential sale of Santee Cooper, a state-owned utility with significant debt due to the abandonment of the V.C. Summer nuclear units 2 & 3. Mr. Ming testified before the South Carolina legislature to present the pros and cons of a potential sale, management arrangement, or reform of the utility.
- **Reliability Risk Model Assessment, PJM, 2021-2024:** Mr. Ming led a team that provided a detailed technical review of the probabilistic reliability risk model used by PJM to calculate capacity requirements and resource accreditation values (including renewables, storage, and thermal) for use in the PJM capacity market. Elements of the model that were reviewed include data inputs, assumptions, algorithms, methods of use, and results. Through this process, E3 made multiple suggestions for improvement to PJM staff.

¹ https://www.ethree.com/wp-content/uploads/2019/06/E3_Long_Run_Resource_Adequacy_CA_Deep-Decarbonization_Final.pdf

² https://www.ethree.com/wp-content/uploads/2019/03/E3_Resource_Adequacy_in_the_Pacific-Northwest_March_2019.pdf

³ <https://interchange.puc.texas.gov/search/documents/?controlNumber=54335&itemNumber=2>

- **PURPA Expert Witness Testimony, South Carolina Office of Regulatory Staff, 2023:** Mr. Ming reviewed Public Utilities and Regulatory Policy Act (PURPA) filings submitted by South Carolina’s investor-owned utilities on behalf of the Office of Regulatory Staff. Mr. Ming reviewed for adherence to rate design best practices and application of avoided cost principles for both energy, capacity, and renewable integration costs. Mr. Ming testified before the South Carolina Public Service Commission to provide an overall assessment as well as recommendations for improvement.
- **Net Zero New England, Calpine, 2020:** Mr. Ming advised on a comprehensive economy-wide decarbonization analysis with a specific focus on the electricity sector. The analysis focused on the operating challenges at higher penetrations of renewables and the role of firm generation in the New England ISO under a net-zero carbon target.⁴
- **ISONE Capacity Market Design, Confidential Client, 2022:** Mr. Ming, on behalf of a confidential client, presented recommendations to the New England ISO (ISONE) on methods and improvements to better reflect winter reliability risks, particularly due to fuel constraints, in reliability risk modeling used in their capacity market.
- **Capacity Market Design, NYISO, 2022:** Mr. Ming advised the New York ISO (NYISO) on best practices for the adoption of a marginal effective load carrying capability (ELCC) framework within their capacity market construct. In 2022, NYISO became the first ISO to receive FERC approval for the implementation of a marginal ELCC framework. E3 also advised on technical implementation details including best modeling practices to balance both accuracy and simplicity.
- **Capacity Market Design, MISO, 2023:** Mr. Ming was retained by the Midcontinent Independent System Operator (MISO) to provide expert testimony regarding MISO’s filing before FERC to implement a “direct loss of load” methodology for use in their capacity market. Mr. Ming also led a team that provided advice on other topics including best practices for assessing local reliability requirements and determining which hours should be utilized in assessing reliability requirements.
- **Offshore Wind Reliability Analysis, Confidential Client, 2022:** Mr. Ming led a team to evaluate the reliability contribution of offshore wind in the PJM market for a confidential client. The team utilized detailed renewable output profiles to calculate effective load carrying capability (ELCC) values across a number of different future years and scenarios. The analysis determined that while offshore wind could make meaningful contributions to reliability, there remained a strong role for firm resources to ensure reliability across all conditions.
- **Firm Generation in Microgrids, Mainspring Energy, 2021:** Mr. Ming developed a report for Mainspring Energy evaluating the role of firm generation in local microgrids in California. E3 evaluated several different microgrid configurations including solar + storage, solar + fuel cell, and solar + Mainspring to determine that the lifecycle economics of solar + Mainspring were superior to alternative options, while providing equivalent emission and reliability outcomes.⁵
- **Renewable Reliability Value Analysis, Lincoln Electric System, 2022:** Mr. Ming oversaw a team that calculated renewable capacity values for Lincoln Electric System (LES) within the context of the Southwest Power Pool (SPP) market. The team calculated a forecast of ELCC values for wind, solar, and battery storage, which were provided to LES for use in their 2022 integrated resource plan.⁶
- **Renewable Effective Load Carrying Capability Analysis, Salt River Project, 2022:** Mr. Ming advised on a project to calculate the renewable effective load carrying capability (ELCC) values for wind, solar, and battery storage for Salt River Project (SRP). These values were used in SRP’s 2022 integrated resource plan.

⁴ https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_November_2020.pdf

⁵ <https://www.ethree.com/wp-content/uploads/2021/03/The-Role-of-Firming-Generation-in-Microgrids-E3-and-Mainspring-Energy.pdf>

⁶ <https://www.les.com/sites/default/files/resource-items/irp-report.pdf>

- **Boulder Canyon Dam Pumped Storage Value Analysis, Los Angeles Department of Water and Power, 2019:** Mr. Ming led a team to evaluate the economics of converting Boulder Canyon Dam into a pumped storage facility to provide value integrating the increasing penetration of renewables in the Western interconnection.
- **Wholesale Market Tariffs, Nova Scotia Power, 2020-2021:** Mr. Ming developed testimony to support reforms to existing wholesale market tariffs to ensure they were consistent with best practices in competitive markets across North America.
- **Transmission Rate Design Analysis, AltaLink, 2017-2021:** Mr. Ming conducted rate design and regulatory analysis on the existing wholesale transmission tariff in Alberta and proposed alternative designs that were more aligned with cost-of-service principles.
- **Capacity Market Design, PJM, 2020-2021:** Mr. Ming provided advice to PJM on the incorporation of the effective load carrying capability (ELCC) metric into the PJM capacity market as a method to quantify the contribution of renewable energy and storage resources. Mr. Ming presented publicly the findings of the project at a PJM stakeholder workshop
- **Whitepaper Series, Regulatory Assistance Project, 2022-2023:** E3 worked with RAP to publish a series of whitepapers targeted to Chinese policymakers on topics related to energy and electricity. The whitepapers were published in English and Chinese and covered the topics of time-of-use ratemaking, integrating real-time pricing into rates, the value of long-term contracting, efficient capacity market mechanisms, the role of clean firm generation in a decarbonized electricity system, and the role of demand response and energy efficiency participation in capacity markets.
- **ERCOT Market Design, NRG, 2021:** Mr. Ming developed a whitepaper outlining a proposal to implement a load-serving entity reliability obligation (LSERO) product in the ERCOT market to both improve reliability and make the state less susceptible to scarcity pricing.⁷
- **California Hydrogen and CCS, Confidential Client, 2022:** Mr. Ming led analysis to evaluate the potential role and value of both hydrogen and carbon capture and sequestration (CCS) in California under the incentives of the Inflation Reduction Act.
- **Pathways to Net-Zero Carbon, Omaha Public Power District, 2021:** Mr. Ming led a study on behalf of OPPD to analyze pathways to net-zero carbon. The study found that significant quantities of wind, solar, and battery storage would be components of a least-cost/least-regrets resource plan, supplemented by firm resources for reliability such as natural gas or hydrogen. Mr. Ming led a series of six public stakeholder workshops to provide an opportunity for transparency and public input.
- **Long-Run Resource Adequacy under Deep Decarbonization Pathways for California, 2018-2019:** Mr. Ming authored a report analyzing the resource adequacy requirements of a high-renewable electricity system, consistent with California's long-term decarbonization goals of 80% by 2050. The report demonstrated that despite significant additions of renewable energy and storage, significant quantities of firm capacity were still needed to maintain sufficient reliability.
- **Reliability Value of Demand Response in California, CAISO, 2019-2022:** Mr. Ming led an effort to study the reliability impacts of demand response in the California electricity system using the effective load carrying capability (ELCC) methodology. The study showed that current methods overvalue the reliability value by 25-50%. Mr. Ming presented the findings publicly at multiple stakeholder workshops.
- **Resource Adequacy in the Pacific Northwest, Public Generating Pool, 2018-2019:** Mr. Ming authored a report analyzing the resource adequacy requirements of the Pacific Northwest under various low carbon electricity systems, including 100% carbon-free. This report was presented to multiple stakeholders and utilities in the region and has led to further discussions around resource adequacy coordination and planning.

⁷ https://www.ethree.com/wp-content/uploads/2021/09/LSE-Reliability-Obligation-E3-ERCOT-Whitepaper_2021-09-29.pdf

- **Once-Through Cooling Retirement Analysis, Los Angeles Department of Water and Power, 2017:** Mr. Ming managed a project analyzing the reliability implications of retiring three once-through cooling natural gas power plants in the Los Angeles basin and replacing them with a combination of clean resources including solar, storage, energy efficiency, and transmission. The results of this study were used to support the decision to retire all three plants and replace them with clean resources.
- **Planning Reserve Margin Study, Nova Scotia Power, 2019:** Mr. Ming led analysis to evaluate the required planning reserve margin (PRM) necessary to achieve a 1-day-in-10 year reliability standard in the province of Nova Scotia. The study also evaluated the contribution of several intermittent and energy-limited resources toward the PRM including solar, wind, energy storage, and demand response. This report was published publicly and formed a basis for Nova Scotia Power's 2020 integrated resource plan.
- **Integrated Resource Planning Support, Confidential Mid-Size Utility, 2018:** Mr. Ming managed a project evaluating the potential replacement of coal resources with renewable, energy storage, and natural gas resources in order to achieve decarbonization targets for a confidential mid-size utility.
- **Net Energy Metering Analysis, Various Clients, 2014-2017:** Mr. Ming performed analysis and published reports for various state utility commissions (California, Nevada, New York, South Carolina) evaluating the costs and benefits of net energy metering policies.
- **Heat Pump Analysis, New York State Energy and Research Development Authority, 2017:** Mr. Ming performed analysis on the costs and benefits of electric heat pumps to replace oil and natural gas heating in New York state as well as increase the efficiency of existing air conditioners. This work was published in a public report that led to the development of policies to incentivize heat pump adoption.
- **Resource Adequacy Program Design, Calpine, 2016:** Mr. Ming performed analysis on behalf of Calpine and presented to the California Public Utilities Commission (CPUC) to recommend the use of the effective load carrying capability (ELCC) metric in the Resource Adequacy (RA) program for wind and solar resources. The CPUC ultimately adopted this recommendation along with several market design features proposed by E3.
- **California Avoided Cost Calculator, California Public Utilities Commission, 2016-2018:** Mr. Ming led an update of the avoided cost forecast used to conduct cost and benefit analysis for demand-side programs in California, including energy efficiency, demand response, and distributed generation.
- **Title 24 Building Standard Development, California Energy Commission, 2016-2017:** Mr. Ming developed a forecast of future energy costs for the State of California used to establish building energy efficiency standards under Title 24.
- **Resource Value of Solar, Oregon Public Utilities Commission, 2016:** Mr. Ming contributed to expert testimony on the resource value of solar before the Oregon Public Utilities Commission.
- **Policy and Technology Scenario Analysis, Confidential Large U.S. Utility, 2015:** Mr. Ming modeled policy and technology-change scenarios for a large U.S utility as part of their strategy planning process.

GENERAL ELECTRIC

Renewable Energy Development Program (REDP) Intern

Schenectady, New York

Summer 2012

CITIGROUP

Commodities Summer Analyst

Houston, Texas

Summer 2011

OGE ENERGY CORP (Enogex)

Capacity Management Intern

Oklahoma City, Oklahoma

Summer 2010

MAP ROYALTY

Oklahoma City, Oklahoma

Engineering Intern

Summer 2009

Education

Stanford University

M.S., Management Science and Engineering (Energy and Environment)

Stanford, California

2013

Stanford University

B.S., Civil and Environmental Engineering (Atmosphere and Energy)

Minor in Economics

Stanford, California

2012