Charlie Duff

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ENERGY AND ENVIRONMENTAL ECONOMICS, INC. San Francisco, CA
Senior Managing Consultant

Mr. Duff joined E3 in 2018 and works primarily in the Integrated System Planning and Asset Valuation and Markets groups. He focuses on utility planning and decision-making processes including both long-term and near-term planning for assets and procurement. He has supported many utility integrated resource plans where he conducts resource planning analyses using E3's RESOLVE model. He also contributes to adjacent projects including the evaluation of specific assets such as the value of adding a carbon capture and storage plant to a utility's resource mix or conducting bid evaluation on bids to fulfill a utility's resource plan. His portfolio of projects also includes transaction diligences on seller side as well as studies that explore impacts of policy reform on markets.

Mr. Duff came to E3 after completing his M.S. in Civil and Environmental Engineering at Stanford University, where his graduate studies focused on energy optimization and power systems modeling. As an intern with the California Independent System Operator (CAISO), Mr. Duff analyzed how solar ramps might affect grid reliability and how variations in ramp rate design could affect the achievement of state RPS goals. In addition to his master's degree, Mr. Duff holds a B.S. in Mechanical Engineering from the University of Wisconsin.

Notable E3 projects include:

- **Utility Bid Evaluation Analysis, Black Hills Energy (2023-2024).** Mr. Duff is supporting the procurement process for Black Hills as they have solicited bids to fill their resource needs, following their Integrated Resource Plan findings. This requires the translation of bids into model inputs and use of E3's RESOLVE model to evaluate which bid(s) would be optimal for the utility to pursue.
- **Integrated Resource Plan Support, Eugene Water and Electric Board (2022-2023).** Mr. Duff provided strategic guidance to EWEB as it conducted its first IRP in over ten years. Mr. Duff's experience in the AURORA model allowed him to support the EWEB modeling team, and his knowledge of resource planning helped the management team identify key questions to answer through sensitivity analysis.
- **Atlantic Loop Transmission Project Valuation, Confidential Transmission Developer (2022-2023).** Mr. Duff was involved in the analysis of the potential Atlantic Loop project in the Atlantic Canadian Provinces for a potential asset developer and investor. This involved using an existing RESOLVE model and performing scenario analysis to determine the value of the project. The transmission line, if built, would help deliver Quebec hydro energy to the other Atlantic Provinces.
- **Zero Carbon Plan Sensitivities, Sacramento Municipal Utility District (2022-2023).** Mr. Duff managed a project for SMUD to explore different strategies for achieving its 2030 decarbonization goal. This involved updating E3's RESOLVE model of the SMUD system to the most current

assumptions and running sensitivity analysis to determine how various assets or pathways would fit into their plan.

- **Offshore Wind Reliability Analysis, Confidential Developer (2021-2022).** Mr. Duff managed a project that explored the ELCCs of offshore wind resources on the East coast that would serve the PJM Interconnection. This required the buildup of a RECAP loss of load probability model to evaluate the reliability across various transmission topologies and assumptions around resource deliverability.
- **Energy Storage Project Valuation and Market Analysis, Confidential Battery Storage Developer (2021-2022).** Mr. Duff led a team that supported a confidential project developer that was seeking to invest in battery energy storage in the SPP market. This involved providing a market overview, investigating potential utilities to seek contracts with, and conducting a valuation using E3's market price forecasts.
- **Illinois Decarbonization Study, Commonwealth Edison (2022).** Mr. Duff supported a study for ComEd that used E3's PATHWAYS and RESOLVE models to identify decarbonization pathways for Illinois, following the passage of the Clean Energy Jobs Act in the State. Aside from this policy, the effort also included identifying and incorporating the impact of the Inflation Reduction Act federal law in the models.
- **Least Cost Carbon Reduction Policies in PJM, Electric Power Supply Association (2020).** Mr. Duff investigated alternative decarbonization strategies in the largest electricity market in the US, PJM. This involved modeling the existing system and its fragmented policies such as state-by-state RPS standards, individual resource mandates and bailouts, and the Regional Greenhouse Gas Initiative (RGGI) in a new RESOLVE model; and then rolling those policies back to replace with a PJM-wide RPS, CES, or GHG cap.
- **Wyoming Wind and Transmission Line Cost-Benefit Analysis, Confidential Transmission Developers (2020).** Mr. Duff used E3's RESOLVE model and AURORA to evaluate the potential benefits of a new transmission line that would deliver high-quality Wyoming wind to entities in the Western Interconnect. This analysis included multiple scenarios to determine the value of Wyoming wind to individual off-takers and an assessment of the various revenue streams the developers could utilize to finance the project.
- **US Economy-Wide Decarbonization Strategies, World Resources Institute; US Climate Alliance (2020-2021).** To determine the effectiveness of potential federal incentives in the electricity sector, Mr. Duff built a new national RESOLVE model. This was used in conjunction with E3's US PATHWAYS model to figure out how various tax policies could be used reduce carbon emissions across all sectors.
- **Integrated Resource Plan Support, California Public Utilities Commission (2020-ongoing).** Mr. Duff has conducted multiple analyses to support the CPUC's IRP process. These include an evaluation of the gas fleet in California to identify plants at risk of retirement, a mid-term system reliability assessment used to determine procurement need, and a study of resource potential for various technology types across the state.
- **Hoover Dam Pumped Storage Financial Analysis, Los Angeles Department of Water and Power (2019-2020).** As part of the E3 team that advised LADWP on the economics of a potential $3 billion pumped hydro storage project, Mr. Duff customized E3's RESOLVE model to the LADWP system in order to quantify the societal and energy market benefits of using solar and wind to pump water into Lake Mead and then use the Hoover Dam as a ~2 GW storage resource.

- **Market Assessment for the Desert Southwest, Confidential Solar Developer (2019-2020).** For a concentrated solar power (CSP) developer, Mr. Duff assessed the economics of deploying their technology in the Desert Southwest. This involved forecasting the annual revenue of a 100 MW project and determining the after-tax equity return, considering the investment tax credit, financing costs, and all costs to develop, build, and operate the project. Mr. Duff performed capacity expansion modeling in California to estimate the market size for the technology over time.
- **Upper Midwest Integrated Resource Plan Support, Xcel Energy (2018-2019).** Mr. Duff advised Xcel Energy on setting corporate greenhouse gas reduction targets after modeling its system, resources, and MISO market interactions in RESOLVE and finding that an 80% reduction by 2030 was eminently achievable; Xcel has since adopted this target. Mr. Duff also conducted extensive analysis in parallel with Xcel's own internal analysis to inform the company's 2020-2034 integrated resource plan, filed with the Minnesota Public Utilities Commission in July 2019, in which the company announced it would close its remaining coal units, extend operations at a nuclear plant, and add 4 GW of renewable resources as part of its decarbonization strategy.
- **Fleetwide Asset Valuation Analysis, Confidential Asset Owner (2018-2019).** To support a confidential client's strategic outlook, Mr. Duff has developed market price forecasts, analyzed CAISO resource adequacy markets, and performed fleetwide economic modeling under several near- and mid-term future scenarios.

STANFORD UNIVERSITY Stanford, CA
Teaching Assistant September 2017 – March 2018
- Led office hours, lab sections, and review sessions and graded tests, homework, and reports
- Lectured on occasion and managed field trips to energy sites in California

CALIFORNIA INDEPENDENT SYSTEM OPERATOR (CAISO) Folsom, CA
Market Quality and Renewable Integration Intern June 2017 – August 2017
- Analyzed grid performance during solar ramps by finding correlations with CPS1 violation
- Provided recommendations for ramp rate design and determined effects on California's RPS goals
- Ran production simulation models to investigate the addition of other balancing authorities into the CAISO market
- Developed tools to interpret results and track energy and money

WISCONSIN ELECTRIC MACHINES AND POWER ELECTRONICS CONSORTIUM Madison, WI
Research Assistant December 2015 – May 2016
- Set up tests and analyzed data for new electric motor design, designed parts on SolidWorks, assembled and disassembled dynamometer, and replaced and installed lab equipment

Professional Activities

Stanford Energy Journal / Wisconsin Engineer Magazine September 2012 – March 2018
Head Editor

- Managed, edited, and wrote energy-related articles of local and global interest for the *Stanford Energy Journal* and *Wisconsin Engineer* and participated in executive meetings

Engineers Without Borders Madison, WI
Project Assistant January 2015 – May 2016

- Sought project partnerships, analyzed potential project engineering costs and environmental and social aspects, communicated with partner NGOs and the community, organized fundraisers, and recruited members

Education

Stanford University Stanford, CA
M.S., Civil and Environmental Engineering (Atmosphere and Energy) 2018

University of Wisconsin Madison, WI
B.S., Mechanical Engineering 2016
Minor in Engineering for Energy Sustainability, International Engineering, and Mathematics