



Charlie Duff

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ENERGY AND ENVIRONMENTAL ECONOMICS, INC.
Managing Consultant

San Francisco, CA

Mr. Duff joined E3 in 2018 and works primarily in the Planning and Markets groups. He works extensively with E3's RESOLVE model to help clients identify least-cost, deeply decarbonized resource portfolios as well as with AURORA to develop credible energy market price forecasts in support of asset valuation and power procurement. 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:

- **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.
- **Retail Rate Analysis, Sacramento Municipal Utilities District (2018-2019).** In determining the potential benefits of a retail rate for commercial and industrial customers during solar curtailment hours, Mr. Duff performed a statistical analysis of historical and forecasted hourly wholesale electricity prices and solar curtailment in multiple scenarios through 2040; incorporated these results into an economic model that calculated customer load shift in response to program design permutations; and projected total economic benefit from the shifted load across forecasted wholesale market scenarios.
- **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.

- **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, Confidential Client (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.

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

Citizenship

United States