Ray C. Duthu *is a graduate research assistant in the Department of Mechanical Engineering at Colorado State University. He is pursuing his Ph.D. research in financial modeling and economic optimization for energy technologies.*

Dan Zimmerle *is Assistant Research Professor at the Powerhouse Energy Institute at Colorado State University and is also Scientific Director at the Center for Research and Education in Wind at the Colorado Renewable Energy Collaboratory. His research concentrates on the development of distributed energy technologies, automated distribution systems, and microgrid controls.*

Thomas H. Bradley *is an Assistant Professor of Mechanical Engineering in the College of Engineering at Colorado State University, where he conducts research and teaches a variety of courses in systems engineering, systems architecture, and techno-economic analysis.*

Michael J. Callahan *is a Senior Project Leader at the National Renewable Energy Laboratory and supports energy systems financial analysis and project development for public and private sector organizations across the globe.*

The authors acknowledge the support of the Joint Institute for Strategic Energy Analysis, which is operated by the Alliance for Sustainable Energy, LLC, on behalf of the U.S. Department of Energy's National Renewable Energy Laboratory; the University of Colorado-Boulder; the Colorado School of Mines; Colorado State University; Massachusetts Institute of Technology, and Stanford University. The authors also acknowledge the contributions of the National Renewable Energy Laboratory staff including Mike Callahan for technical contributions, and Brent Rice and Adam Warren for their helpful suggestions.

Evaluation of Existing Customer-owned, On-site Distributed Generation Business Models

This article presents an economic model that studies customer-owned and operated distributed generation facilities. Results show that customer-optimized distributed generation facilities create quantifiable losses for distribution and generation and transmission utilities, and that further work will be required in order to create new business models that equitably share in the potential technical and economic benefits of distributed generation.

Ray C. Duthu, Daniel Zimmerle, Thomas H. Bradley and Michael J. Callahan

I. Introduction

A variety of Smart Grid analysis and optimization studies have concluded that customer-owned and customer-operated distributed generation (DG) can realize specific economic benefits for utility customers.[1,2,3,4] These studies of DG operation and control have focused on rigorous minimization of customer costs, without consideration for the other stakeholders in the DG transaction. Previous research has already investigated multi-objective optimized solutions that balance customer economics with environmental concerns,[5] but there has been little research that simultaneously considers the economic effects of DG on all of its market participants. If properly sited and implemented,[6] DG

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2013.12.008

facilities benefit utilities through grid capacity upgrade/expansion deferrals and reduced demand (i.e. reduced costs), but there is not currently a thorough understanding of the net economic effect of a DG facility for distribution or generation and transmission (G&T) utility stakeholders. Utilities are primary stakeholders in the electrical market and their participation and buy-in to customer-owned DG business models will determine the degree to which the capabilities of DG will be realized in practice.[7]

Existing DG systems' business models[8] function by operating the distributed generator during any time when the levelized cost of generation using the DG resource is lower than the cost to purchase electricity from the utility.[1,2,3,4] Although this business model is simple, transparent, and has been demonstrated to provide value to the electricity customer, the long-term acceptability and viability of DG must account for real-world utility/customer interactions and interdependencies. A complete and effective utility business model is asserted by EPRI to require the following: (1) revenues must cover costs, (2) services must be performed reliably, and (3) costs and revenues must be allocated equitably among the stakeholders.[9]

Fort Collins, Colo., is the site of FortZED, a comprehensive community effort to create a zero-energy district in the downtown and university areas. The FortZED organizations participated in a U.S. Department of Energy Renewable Distributed Systems Integration (RDSI) Smart Grid demonstration. The RDSI attempted to lower the peak electrical load on two active distribution feeders (of approximately 15 MW capacity) by 20–30 percent through the implementation of customer-owned and customer-controlled DG systems. During the development of the demonstration, a first order analysis performed by the Platte River Power Authority (PRPA) using its traditional business models indicated that the FortZED DG program, active for approximately 300 hours/year, could cost PRPA more than $400,000 per year.[10] The primary driver of this financial impact was the reduction in the customer's charges related to coincident peak pricing, and secondarily, reduction in demand charges. This single real-world data point would suggest that traditional utility business models applied to DG may not meet the requirements for an effective business model as defined above. Beyond this local example, this hidden cost of DG is typical for many utilities and it has led to significant utility opposition against DG resources, limiting the use and benefit of these technologies.[11]

Currently, there is not a thorough understanding of the net economic effect of a DG facility for distribution or generation and transmission utility stakeholders.

The goal of this study is to build on this example and the current state of the art in analysis of customer-owned DG systems, to more completely understand how the demands of customer-owned and operated DG function within current business models. This article presents financial models of the utilities involved in FortZED to more comprehensively understand (1) the business model that is currently motivating the development and control of customer-owned and operated DG resources, (2) the means by which utilities' costs and revenues can be affected by the DG resources, and (3) which alternative business models can create economic value from DG technology. Armed with this information, stakeholders for the Smart Grid technology can understand the true costs and benefits of DG to the utilities and other stakeholders.

II. Methods

A. Modeling scope

The financial model discussed in this article was built as a case study representative of DG

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2013.12.008