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# Modeling an aggressive energy-efficiency scenario in long-range load forecasting for electric power transmission planning

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## HIGHLIGHTS

- Improved representation of end-use energy efficiency is needed for load forecasting.
- An emergent application is long-range electric power transmission planning.
- A "hybrid" econometric-technology forecasting approach incorporates efficiency.
- A high efficiency scenario was created for Western U.S. transmission planning.
- Significant load-growth reductions from increased end-use efficiency are possible.

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## ABSTRACT

Improving the representation of end-use energy efficiency, and of the effects of policies and programs to promote it, is an emergent priority for electricity load forecasting models and methods. This paper describes a "hybrid" load forecasting approach combining econometric and technological elements that is designed to meet this need, in a novel application to long-run electric power transmission planning in the western United States. A twenty-year load forecast incorporating significant increases in energy-efficiency programs and policies across multiple locations was developed in order to assess the potential of efficiency to reduce load growth and requirements for expanded transmission capacity. Load forecasting and transmission planning background is summarized, the theoretical and empirical aspects of the hybrid methodology described, and the assumptions, structure, data development, and results of the aggressive efficiency scenario are presented. The analysis shows that substantial electricity savings are possible in this scenario in most residential and commercial end-uses, and in the industrial sector, with magnitudes depending upon the specific end-use as well as upon the geographic location of the utility or other entity providing the electricity.



## 1. Introduction

Analyzing and projecting consumers' and firms' consumption of electricity is one of the core applications of computational energy modeling. Over the past several decades, various methods for this problem of "load forecasting" have been applied by electric utilities, energy policy-makers, and other decision-making entities in the electric power system. Recently, new technological and policy developments related to electric power production, transmission, and consumption have placed new demands upon load forecasting methodologies. Expanded features including increasing levels of detail, longer time horizons, and the capacity to address an expanded set of policy and regulatory requirements, are being required in load forecasting models' range of functionality.

Improving the representation of end-use energy efficiency, and of the effects of policies and programs to promote it, are among the priorities for enhancing load forecasting models and methods. Efficiency has become an important element of many utilities' resource mix for meeting the demand for electrical energy services, as well as a key component of numerous policy portfolios for large-scale abatement of carbon dioxide emissions from the electric power system. Such developments necessitate new approaches, and extensions of existing approaches, to load forecasting.

This paper describes such an approach in application to an important example of emerging problems in load forecasting:

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**Nomenclature**

| | |
|---|---|
| AEO | Annual Energy Outlook – U.S. national energy forecast, produced by EIA using NEMS |
| BA | balancing authority – electric power control and planning area |
| CHP | combined heat and power |
| COP | coefficient of performance – metric of heating or cooling output per input of electric energy; an index of energy efficiency |
| Diversity factor | ratio of coincident peak demand for a BA (BA load at time of WECC system-wide peak)to non-coincident peak (actual BA peak value) |
| DSM | demand-side management – programs (usually by electric utilities) to reduce or change end-use energy and/or peak demand, including through promoting end-use efficiency |
| EER | energy efficiency ratio – for a cooling device, ratio of cooling output in btu to electrical input in watt-hours at a given operating point |
| EIA | Energy Information Administration – U.S. national energy statistical and analytical agency, within the U.S. Department of Energy (but reporting to the U.S. Congress) |
| EMMA | environmental and emission model for Adam – Danish energy model |
| HSPF | heating seasonal performance factor – ratio of heating output in btu to electric energy consumed to produce it, both over a season; a metric of energy efficiency |
| HVAC | heating, ventilation, and cooling |
| LSE | load-serving entity – a company or organization providing electricity services to retail or wholesale customers |
| NEMS | National Energy Modeling System – U.S. national energy forecasting model, maintained and used by EIA |
| SAE | statistically-adjusted end-use – load forecasting methodology combining econometric and technology end-use elements and techniques |
| SEER | seasonal energy efficiency ratio – For a cooling device, ratio of cooling output over a season to electrical input over the same period |
| UEC | unit energy consumption – metric of energy efficiency for certain types of devices; typically in kW h per year |
| WECC | Western Electricity Coordinating Council – electric power transmission planning and operations organization in the Western U.S |
| WI | Western interconnect – component or grid of the North American electric power system, serving the Western U.S. and Canada and Northern Mexico |

Incorporating energy efficiency into long-run electricity transmission planning. The approach is a "hybrid" load forecasting and modeling framework combining econometric and technological elements, focusing on a higher level of aggregation than is commonly incorporated in standard efficiency potential studies, while still allowing for the representation of end-use technology detail.

Transmission planning itself is undergoing significant changes to meet new policy priorities and regulatory constraints, including the expanded deployment of renewable energy sources and increased requirements for system reliability. The analysis discussed here was undertaken in support of a multi-institution, multi-stakeholder initiative to improve transmission planning in the Western Electricity Coordinating Council (WECC), a federally-sanctioned transmission operations and planning organization. Projections of future load growth across the WECC and scenarios of expanded energy efficiency programs and policies were created in order to examine the implications of increased efficiency for the development of the transmission system. The purpose was to enable subsequent analysis, using transmission planning modeling, of how greater end-use efficiency, by reducing load growth, might affect requirements for future transmission capacity expansion. In this paper we describe the design and implementation of a scenario of aggressive efficiency or high "demand-side management (DSM)" programs, policies, and regulations that would significantly increase the deployment of efficient end-use technologies across the WECC and therefore substantially reduce load relative to the projected baseline.[1]

The paper is organized as follows. In the next section, we provide background on load forecasting, transmission planning and the WECC, and the genesis of the load forecast and aggressive efficiency scenario. Following this is a summary of the SAE framework and methodology, basic data inputs for this analysis, the representation of DSM impacts within the hybrid load forecasting framework, the treatment of uncertainty and model sensitivity, and a comparison to other approaches. Section 4 then presents the core content of the paper: the assumptions, structure, inputs, and results of the High DSM scenario. The paper ends with a discussion and concluding remarks.

## 2. Background

### 2.1. Energy efficiency and methods of load forecasting

Load forecasting methods in general have been the subject of a number of relatively recent surveys, including [2–5]. In this section we focus specifically on the issue of energy efficiency in the load forecasting context, and in Section 3.5 further discuss forecasting approaches.

Utilities increasingly treat efficiency as a resource analogous to conventional power generation, and are changing generation investment plans based on anticipated efficiency acquisitions. Indeed, DSM programs and other efficiency policies are among the causes of steadily slowing electricity sales growth in recent decades [6]. The expanding implementation of these programs is stimulating changes to forecasting procedures.

Traditionally, one or more of three methods have been used for electric utility load forecasting: (i) Extrapolation of past trends; (ii) Econometric modeling; (iii) Technologically-detailed end-use energy modeling [7]. Each method remains in use, although the econometric approach has come to predominate. In this approach, load is predicted as a function – typically linear – of inputs including weather (usually heating and cooling degree days), demographic and income (for residential) or building stock (often square-footage, for commercial) variables, and prices, plus an error term. The time-unit of analysis can be hourly, monthly, or annual. Parameters are estimated on historical data.

Regarding end-use energy efficiency, this approach captures the future, ongoing effects of utility DSM, and policies such as building or appliance minimum-efficiency standards, that are reflected in historical data. At the utility level, however, some adjustment of load forecasts is needed to account for additional impacts that might result from expanded or additional future programs. The

[1] Additional detail on the work described in this paper is contained in a longer technical report [1]. Demand-side management includes energy efficiency as well as load management by end users.