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An economic comparison of battery energy storage to conventional energy efficiency technologies in Colorado manufacturing facilities

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HIGHLIGHTS

- Energy storage's and efficiency technologies' economic payback is compared.
- Conventional efficiency technologies have shorter payback for the customers studied.
- Hypothetical incentives can lower the payback periods of battery energy storage.

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ABSTRACT

Battery energy storage (BES) is one of a set of technologies that can be considered to reduce electrical loads, and to realize economic value for industrial customers. To directly compare the energy savings and economic effectiveness of BES to more conventional energy efficiency technologies, this study collected detailed information regarding the electrical loads associated with four Colorado manufacturing facilities. These datasets were used to generate a set of three scenarios for each manufacturer: implementation of a BES system, implementation of a set of conventional energy efficiency recommendations, and the implementation of both BES and conventional energy efficiency technologies. Evaluating these scenarios' economic payback period allows for a direct comparison between the cost-effectiveness of energy efficiency technologies and that of BES, demonstrates the costs and benefits of implementing both BES and energy efficiency technologies, and characterizes the effectiveness of potential incentives in improving economic payback. For all of the manufacturing facilities modeled, results demonstrate that BES is the least cost-effective among the energy efficiency technologies considered, but that simultaneous implementation of both BES and energy efficiency technologies has a negligible effect on the BES payback period. Incentives are demonstrated to be required for BES to achieve near-term payback period parity with more conventional energy efficiency technologies.

1. Introduction

The rate structures that are commonly in place for small to medium-sized manufacturers can provide incentives for energy efficiency, peak demand reductions, and load shifting. For Colorado manufacturing industrial facilities, the costs of electrical energy service is broken up into three or four scalable costs: a connection cost (with a price measured in $ per connection), an energy cost (with a price measured in $ per kilowatt-hour), a peak demand cost (with a price measured in $ per kilowatt), and a coincidental demand cost (with price also measured in $ per kilowatt). Utility companies calculate peak demand in kilowatts (kW) by measuring fifteen minute intervals of the user's energy consumption, in units of kilowatt hours (kW h), and dividing it by the amount of hours in that interval, 0.25 h [1]. They then sort these demand calculations for an entire month, and the maximum demand calculated is the peak demand. This means a single fifteen minute period in a month dictates the cost a customer pays for peak demand for the entire month. Coincident demand is the customer's electric demand during the one hour each month, called the peak hour, where the wholesale electricity generation and transmission provider supplied the highest load [2]. The high price of these demand costs generally incents consumers to minimize both their peak loads and their loads during the typical peak hour (e.g. early evening in the winter and mid-afternoon in the summer) [27].

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The most common methods of reducing peak demand and loads during the peak hour are implementing new or retrofit energy efficient technologies and load shifting techniques. As advancements in technology are made, new products become available that can either replace or be added to an existing piece of equipment to improve its energy efficiency (e.g. variable frequency drives, high-efficiency motors, light emitting diode (LED) lighting). These energy efficient technologies effectively reduce the total peak and peak hour loads by reducing the load of that equipment during its hours of operation [3,4]. Manufacturers implement these energy efficiency technologies preferentially because of their cost-effectiveness and the presence of utility incentives [5]. Load shifting is another preferred technique for reducing demand charges [6,7]. Load shifting lowers the peak and peak hour loads by moving the time or intensity of operation of individual equipment to lower cost times of the day. This can be done a variety of ways including technologically (e.g. thermal storage [8], demand controllers [7]) and manually through equipment operational scheduling and employee training. Although this method has the potential to be more successful at lowering peak and peak hour loads than energy efficient technologies, it is dependent on the individual equipment loads that make up the peak and peak hour total load [8]. Furthermore, it is much harder to implement this method in manufacturing facilities, as shifting equipment loads can interfere with the manufacturing process and cut into the productivity, and thereby the profits, of that facility [7–11].

Behind-the-meter (BTM) battery energy storage (BES) systems aim to reduce electricity costs by providing a way to redistribute the peak and peak hour loads without the productivity losses that might be associated with standard load shifting techniques. Although there has been research on BES in several applications such as electricity grid frequency regulation [12,13] and renewable generation storage [13–16], the business case for near-term BES is not well-defined. BES technology is presently being pushed to market through mandates and incentives. As an example, in California, the California Public Utilities Commission (CPUC) has set a procurement target of 1.325 GW of energy storage (including BTM) by 2020, for installation no later than 2024 [20]. Several studies have shown BTM BES to have moderate potential for lowering the peak demand of a facility and thereby the associated costs in a behind-the-meter (or customer-sited) application [12–19]. However, these studies have not sought to consider BTM BES as one of a set of energy cost saving technologies that could be implemented separately or together, and have not been able to consider BES's role among the set of energy and cost saving technologies. If energy efficient technologies and load shifting techniques were to be applied at the same facility as a BTM BES system, the value of BES in reducing energy costs may be misestimated by the models currently proposed in literature.

With the pathway toward commercialization of BTM BES already in progress, the energy cost savings associated with BES should be assessed relative to other energy efficiency technologies and more common load shifting techniques. To perform this evaluation, this study measures a broad set of loads in four case study industrial facilities, and proposes the implementation of both BES and more conventional energy efficient technologies for each facility. The electricity cost savings and payback period associated with each of these technologies can thereby be directly compared to that of BES. This analysis allows us to understand the implications of installing conventional energy cost reduction technologies prior to BES, directly compares the cost-effectiveness of these technologies to BES, and provides insight as to what the utility incentives in Colorado would need to be to bring BES into payback parity with other energy cost saving technologies.

2. Materials and methods

2.1. Summary

This research is based on four case studies of different types of manufacturing facilities located in Colorado, USA. In each of these facilities, the electrical loads associated with large operational equipment were data-logged and the total electrical load of the facility was collected. Other observational information that could shed insight on how energy was being used was also gathered. Using the information gathered, the estimated costs and savings of applicable new and retrofit energy efficient technologies were calculated using Department of Energy (DOE) and CSU Industrial Assessment Center (IAC) toolsets. To assess the cost-effectiveness of BES for each case study, the National Renewable Energy Lab's (NREL) Battery Lifetime Analysis and Simulation Tool for Behind-the-Meter applications (BLAST-BTM) was used to estimate the costs and savings at each facility both before and after the estimated savings were applied to the collected load profile. The cost-effectiveness for all of these technologies are compared using the metric of payback period, which has shown to be a primary consideration in an industrial facility's decision to implement energy efficiency measures [21–25].

2.2. Data gathering and acquisition

A walk-through of the facility was performed at each manufacturing plant to gain an understanding of the manufacturing process, and to locate large energy uses in the facility. While on the walk-through, specific information was gathered that would later assist in estimating the savings of energy efficient technology including hours of operation, lighting counts, nameplate information on outdated or energy inefficient equipment, air leak identification, and more. One to two pieces of equipment that represented a significant contribution to the facilities' total load were then data-logged using HOBOware data loggers (Onset Computer Corporation, Bourne, MA) and set to record for two week periods. This data collection period was chosen due to time constraints determined by the plants and the storage capacity of the data loggers. Data were collected on intervals varying from ten seconds to one minute, and were averaged in MATLAB to fifteen minute intervals as this is the collection period considered by the utility for peak demand and coincident demand cost calculations. The total load of each facility over the same two week period was also collected either using a power quality analyzer in three minute intervals and averaged to fifteen minutes or in fifteen minute intervals in datasets provided by the utility. The benefit of logging the individual loads of large equipment is that it adds depth to our understanding of the electrical loads by showing how each load interacts and contributes to the total load of the facility, especially during peak and peak hour loads (Fig. 1). Additionally, when calculating the energy savings that might be associated with retrofit technology, we can apply that savings only to periods when that machine is on instead of applying it over the total load profile during the estimated hours of operation. The information obtained in the walk-through and data collection was then used to identify applicable new and retrofit energy efficient technologies and to estimate the associated costs and savings.

2.3. Modeling of energy efficiency technologies

IAC toolsets developed over the 31 years of Colorado State University's IAC program, validated and approved by the DOE IAC program management, were used to estimate the associated energy savings of implementing energy efficient new and retrofit