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CASE STUDY

An improved strategic decision-making model for energy conservation measures

Billy R. Champion*, Steven A. Gabriel

Civil Systems Program[1], Department of Civil & Environmental Engineering, University of Maryland, College Park, MD 20742, USA

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ABSTRACT

Energy Conservation Measure selection is made difficult given real-world constraints, limited resources to implement savings retrofits, various suppliers in the market and project financing alternatives. The most common method of implementation planning is suboptimal. This paper presents a model that decision-makers can use to optimize the selection of energy conservation measures. The practical application should supplement current best practices for agencies concerned with making the most cost-effective selection.

1. Introduction

The federal government has consistently been the largest consumer of energy using almost 1.2 quadrillion BTUs (British thermal units) per year from all fuel sources in the United States. The cost of meeting the Federal Government's facility energy costs had grown to $6.5 billion per year in 2007 [1]. State and local governments spend an additional $10 billion a year on energy to provide public services and meet constituent needs.

In 1978, the United States Congress signed The National Energy Conservation Policy Act (NECPA) into law. This law is the basis for federal energy management goals and requirements in the United States. The overall purpose of the law was to promote the conservation and the efficient use of energy and water, and the use of renewable energy sources by the Federal Government. The resulting goals for energy performance were issued for federal buildings mandated and it was mandated that each Agency apply energy conservation measures (ECMs) and improve the design for construction so that the energy consumption per gross square foot was reduced [2]. The NECPA also gave federal agencies the authority to enter into shared-energy savings contracts with private-sector energy service companies (ESCOs). The NECPA has been regularly updated and amended by subsequent laws and regulations. One such regulation is the Energy Independence and Security Act of 2007 (EISA 2007), which established energy management goals and requirements while also amending portions of the NECPA.

These Congressional Acts mandate specific goals and targets including:

- Reducing energy intensity (Btu/ft^2) by 15 percent by the end of FY 2010, compared to a FY 2003 baseline and by 30 percent by the end of FY 2015;
- Increasing renewable electric energy equivalent to at least five percent of total electricity use in FYs 2010–2012 and at least 7.5 percent in FY 2013 and beyond; at least half must come from sources developed after January 1, 1999; and
- Achieving a 20 percent reduction in vehicle fleet petroleum use by 2015.

Overall, federal agencies must enhance efforts towards sustainable buildings and communities. Specifically agencies must implement high performance sustainable federal building design, construction, operation and management, maintenance, and deconstruction by ensuring all new federal buildings, entering the design phase in 2020 or later, are designed to achieve zero net energy[2] by 2030 (see Fig. 1)

* Corresponding author.
E-mail address: champ3@umd.edu (B.R. Champion).
[1] www.civilsystems.umd.edu.

[2] A zero net energy building is one with zero net energy consumption. The total amount of energy used by the building on an annual basis is less than or equal to the amount of renewable energy created on site.

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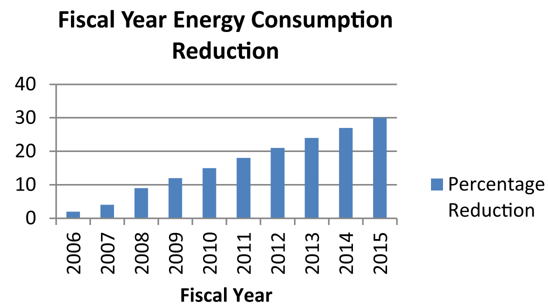

Fig. 1. Required reduction in energy consumption.

The central objective is clear; buildings must reduce their energy consumption. However, the secondary objective of lowering spending on energy, while adding the cost of implementing energy savings measures complicates the directives. Implicit to the mandates of reducing energy consumption and lowering energy spending is the assumption that both are known, easily measured and reported.

Faced with the multitude of requirements with the ultimate objectives of conserving energy and lowering spending, many agencies and property owners/managers find themselves with a computational challenge. There is a clear understanding of the extent to which energy efficiency must be achieved but a clear path to achieving these goals has not been dictated. Fortunately, there is an industry standard for best practice [3]. The primary tool that the Agency's decision-makers use is the energy audit. There are several types of audits, however; an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) level 2 or 3 is most often used for planning and decision-making [4].

The audit is a comprehensive energy analysis and assessment of the building's energy-using components such that a list of energy conservation measures can be proposed with the following attributes:

- the proposed system or component description
- each measure's required investment
- the annual savings by fuel source
- the annual cost savings in dollars
- measure of such as simple payback ratio or savings to investment ratio

The energy auditors have assessed the regulatory requirements and conducted an audit which recommends the projects necessary to save the requisite energy. All projects must be completed. The Agency's approach to implementing these projects has been the naïve method, which involves sorting by cost/benefit then selecting until the budget has been depleted. They have not leveraged the integer programming approach that solves a resource allocation problem to choose a subset of projects to optimize savings (a "knapsack" problem).

Given this list of ECMs, the Agency's decision-maker faces a series of strategic decisions. Each project from which the energy manager or decision-maker must select, saves energy or annual energy costs and, in most cases, both. Simpler projects can often be implemented with in-house resources and staff. Lower-cost projects can often be financed with internal operating budgets. Using in-house budgets and resources provide the best return on investment. These projects also free up capital for further energy projects. Higher risk, more difficult or projects that require large capital investment can be performed by Energy Service Companies per the guidance first issued in NECPA. The energy performance contracts (EPCs) completed by the ESCOs do not yield the cost savings that in-house projects do as the cost savings are shared with the ESCOs.

The largest opportunity for energy conservation lies in the creation of the plan. Optimization is needed to properly create a plan that maximizes the energy savings while identifying financing and firms available to implement the recommended measures. The appropriate method of achieving these goals has not been regulated. The standard method of creating this plan segments these decisions. The Agency traditionally selects the projects with the quickest paybacks. Only the least desirable or most costly projects are left for ESCOs. As a result, many agencies select a subset of projects to complete internally only to find that the remaining projects can no longer be completed with a decent payback for firms in the market. In contrast, many agencies allow the audit providers to choose the appropriate projects for them. This selection process may not be aligned with the Agency's objectives.

Furthermore, in the current practice, the Agency may leave a subset of projects incomplete assuming that ESCOs will complete them. The current selection process can generate a mix of selected projects that might not maximize the Agency's share of the benefit (in dollars) of the energy saved. Given the profit maximization objectives for of these firms, it is possible that the Agency will have chosen to take care of projects themselves that will leave the remaining ones unattractive to ESCOs and therefore the whole set of projects will be incomplete. Thus, the current procedure may be ineffective as it does result in the completion of all projects.

2. Literature review

Project selection that optimizes the Agency's value of the total energy saved continues to elude decision-makers. Many approaches of this type of problem have been studied however; none have been applied to energy conservation. The Agency selection problem is a related to the classical knapsack problem which is described below.

Dantzig [5] described and demonstrated methods of solution to the knapsack problem. In this problem, for example, a person is planning a hike and has decided not to carry more than 70 lbs. of different items, such as a bed roll, Geiger counters, cans of food, etc. The hiker would like to maximize his/her benefit of these items while remaining below the weight limit. Dantzig noted that in these types of problems, extreme point solutions (to the corresponding linear program) may yield values which are neither one nor zero (which correspond to selection or omission of items). In Dantzig [5], it was noted that extensions to two or more limitations, for example, one on total weight and another on total volume can be done, but there would be a considerable increase in the amount of computational work. In the current context the weights are the projects' costs and the weight limitation is the budget.

Markowitz [6] wrote that the process of portfolio selection (similar to some extent to project selection) may be divided into two stages: observation and experience, leading to beliefs about the future performances and the relevant beliefs about future performance leading to the choice of portfolio. Selecting the highest anticipated return may leave projects undone and violate a key constraint. The current problem should incorporate constraints on the purchases, mainly that the Energy Manager cannot maximize the Agency's share of savings without the profit maximization of lower-level firms such as ESCOs and Contractors.

In Gabriel et al. [7], a multi-objective, integer-constrained optimization model with competing objectives for project selection was proposed in which probability distributions were used to describe uncertain costs. That model was novel since it integrated multi-objective optimization, Monte Carlo