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Authors
Blass, Vered
Corbett, Charles J.
Delmas, Magali A
et al.

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Vered Blass
The Recanati Graduate School of Business Administration, Tel Aviv University, Tel Aviv, 69978, Israel, vblass@post.tau.ac.il

Charles J. Corbett
Anderson School of Management, University of California, Los Angeles, California 90095-1481, charles.corbett@anderson.ucla.edu

Magali A. Delmas
Institute of the Environment & Anderson School of Management, University of California, Los Angeles, California 90095-1496, delmas@ucla.edu

Suresh Muthulingam
Johnson Graduate School of Management, Cornell University, Ithaca, New York 14853-6201, muthulingam@cornell.edu

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Charles J. Corbett
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Magali A. Delmas
Institute of the Environment & Anderson School of Management, University of California, Los Angeles, California 90095-1496, delmas@ucla.edu

Suresh Muthulingam
Johnson Graduate School of Management, Cornell University, Ithaca, New York 14853-6201, muthulingam@cornell.edu

Abstract

This paper investigates the role of top management in the adoption of energy-efficiency initiatives. We study data from 175 energy efficiency assessments done by San Diego State University (SDSU) during 2000-2008 as part of the Department of Energy's Industrial Assessment Center Program. We find that top management involvement leads to firms adopting 30% more of the savings identified in an assessment. We also find that when top management is involved, the average payback of adopted proposals is 57.7% longer. When top managers do reject a recommendation, they are more likely to cite operational barriers, as opposed to economic or organizational ones, than other employees are. Altogether, this suggests that top managers perceive less resource constraints than other managers do and adopt a longer perspective on energy efficiency investments. Overall, our findings shed new light on how top management involvement influences the adoption of process innovations.

Keywords: Environmental Operations, Empirical Research, Energy Efficiency, Adoption, Top Management

1. Introduction

Energy efficiency has been recognized since the early 1970s as being profitable and desirable, and its promise as a key strategy against climate change (IPCC, 2007) further enhances its appeal. A considerable body of evidence indicates that a significant proportion of energy efficiency improvement potential remains untapped and that many energy efficiency investments are not undertaken despite their apparent profitability (Expert Group on Energy Efficiency, 2007; Decanio, 1993). Many explanations have been provided in the literature, ranging from economic factors and complexity of regulation (Mueller, 2006) to organizational barriers such as misplaced incentives, risk aversion and shortsightedness of management (Blumstein et al., 1980; Decanio, 1993). While the lack of top management interest in energy efficiency has been deplored and suggested as a probable contributing factor (Sassone and Matucci, 1984), the exact role of top management in the adoption of energy-efficient solutions has been largely unexplored. In this study, we aim to fill this void and investigate the impact of top managers on the adoption of profitable energy-efficiency initiatives.

Our analysis is based on data from 175 energy efficiency assessments done by San Diego State University (SDSU) during 2000-2008 as part of the Department of Energy's (DOE) Industrial Assessment Center (IAC) Program. We find that the involvement of top management does not lead to more recommendations being adopted, but does result in a higher proportion of potential savings being realized than when top management is not involved. Top management involvement also leads to recommendations with longer payback being adopted. Moreover, when top managers reject a recommendation, they are less likely to cite economic or organizational (as opposed to operational) barriers than other managers and employees (thereafter referred as employees). Altogether, this suggests that top managers perceive less stringent financial constraints and that they might adopt a longer perspective on energy efficiency investments as compared to other employees. Our results therefore indicate that top management involvement facilitates energy savings, because they are able to remove internal economic and organizational barriers that other employees find difficult to overcome.

This paper aims to make several contributions. First, it seeks to measure the impact of top management involvement on the adoption of energy efficiency projects. This knowledge can help advance adoption of energy efficiency initiatives. Second, the paper seeks to contribute to the literature on the role of top management in the adoption of process innovations. Contrary to the extant literature (reviewed below), which finds that top management does not influence adoption of process innovations, our findings indicate that top management does play a significant role, not by adopting more innovations, but by adopting innovations with higher savings.

This paper is organized as follows. In section 2, we review the literature on energy efficiency. In section 3, we develop our hypotheses. In section 4, we describe the data and measures used. Section 5 outlines our methodology. Our results are presented in section 6. In section 7, we summarize our main findings, discuss policy implications and suggest areas for additional research.

2. Literature Review

Our work draws on, and contributes to, several streams of literature: on the diffusion of innovations generally and on the role of top management in particular, and on the energy-efficiency gap generally and the impact of organizational factors in particular. We defer a more detailed discussion of the literature pertaining to our specific hypotheses to the next section.

Several categories of innovations are recognized in the literature. Administrative innovation represents new procedures, policies, and organizational forms; technical or technological innovation represents new technologies, products and services (Daft and Becker, 1978). Technical innovation can be divided in two categories: product and process innovations. A technological process innovation is the adoption of “new or significantly improved production methods, including methods of product delivery” (OECD, 1997: 49). Technical process innovations with a high degree of new knowledge are called “radical” innovations, those with a low degree of new knowledge are “incremental” (Dewar and Dutton, 1986). Most of the energy efficiency initiatives in our study are “incremental process innovations.”

The literature has studied the influence of top management on the adoption of incremental process innovations. Thompson (1965) finds a negative relationship between centralization and innovation, as a participatory work environment facilitates innovation by increasing organization members’ awareness, commitment and involvement. Daft and Becker (1978) argue that low professionalism, high formalization, and high centralization facilitate administrative innovations, while the inverse conditions facilitate technical innovations. Ettlie et al. (1984) argue that structural complexity and decentralization should lead to more incremental innovations. Similarly, Dewar and Dutton (1986) and Khan and Manopichetwattana (1989) argue that top managers are irrelevant or even have a negative impact on implementation of process innovations. This literature points to a reduced role of top management on process innovations in general though it does not specifically address energy efficiency.

The energy-efficiency literature proposes several explanations for the underinvestment in energy efficiency, including organizational and information failures. Organizational failure occurs when firms face the so-called “split incentive” problem, involving “transactions or exchanges where the economic benefits of energy conservation do not accrue to the person who is trying to conserve” (Golove and Eto, 1996). Another cause for organizational failure may be the alleged shortsightedness of management (DeCanio, 1993; Jaffe and Stavins, 1994; Thollander, 2008). This myopia would explain why energy efficient investments require shorter payback periods or very high internal hurdle rates as compared to other investments (DeCanio, 1993; Ross, 1986; Sorrell et al., 2000). This literature also suggests that energy conservation may not attract top management interest and therefore be given lower priority than other investments with similar payback (Sassone and Martucci, 1984). Although the literature focuses on cognitive or psychological factors, it has paid less attention to the question of whether and how top management involvement impacts energy efficiency decisions. Furthermore the literature tends to analyze adoption of each innovation independently. Because managers typically consider multiple energy improvement opportunities at the same time, it is more appropriate to examine adoption considering the full set of available opportunities.

Information failure might occur because it may be costly to acquire information about energy efficient solutions, leading to underinvestment (Howarth and Sanstad, 1995). The DOE's IAC program aims at reducing the cost of acquiring information about energy efficient solutions by providing free energy assessments to small and medium-sized firms and has been in place since 1976. However, underinvestment in energy efficiency persists, as implementation rates for the IAC program hover around 50% even though the payback of projects is usually less than two years (Woodruff et al., 1997; Anderson and Newell, 2004). The DOE published an extensive analysis of the IAC program in March 1996, including an examination of the reasons given for rejecting projects (Woodruff et al., 1997). Several scholars have explored additional causes for the underinvestment in the context of the IAC program. For instance, Anderson and Newell (2004) use a conditional logit model to predict adoption probability of each individual recommendation using parameters such as payback period, saving, and implementation cost. Their results suggest that adoption depends more on initial cost than on annual savings. More recent analysis (Muthulingam et al., 2011) replicates and extends Anderson and Newell's work, finding that several behavioral factors, such as the sequence in which recommendations are presented, influence adoption rates. However, a comprehensive explanation for the low rates of adoption of energy efficiency recommendations remains elusive.

Overall, several studies in the innovation and energy-efficiency literatures have contributed to a deeper understanding of the role of organizational factors on the adoption of technical process innovations. However, in the context of top management involvement two questions remain unexplored. The first relates to the fact that the literature tends to examine adoption of each innovation independently, rather than looking at the full portfolio of possible innovations. The second relates to whether the type of managers involved impact the implementation rates of energy efficiency solutions. To address these questions, we develop hypotheses grounded in the literatures on barriers to energy efficiency, managerial involvement in decision-making, and diffusion of innovations, focusing on the effect of top management involvement on energy assessments with multiple recommendations.

3. Hypotheses

While the innovation literature shows that decentralization and a minimized role of top managers facilitate the implementation of technical process innovations, we argue that this might not hold for energy efficiency and that top management has an important role to play. We contend that centralization is necessary to assess the impact of energy efficiency on the whole organization and that top management brings a more appropriate investment-focused perspective than other employees do. In addition, top management has access to resources that facilitate the adoption of energy efficient innovations.

First, centralization mitigates some of the information requirements associated with assessing energy savings. Firms are complex organizations where agents with differing processing capabilities exchange information and make decisions (DeCanio, 1998). Scholars have shown how organizations can be inefficient in transmitting information as a function of network structure (Yamaguchi, 1994) and how middle management, for example, can influence top management decisions by concealing important information, and by framing the issues in particular ways (Dutton and Ashford, 1993). Because energy efficiency information can be costly to acquire, it might benefit from a centralized approach where the information is processed by a centralized agent with a broad view of the organization's interests.

Second, we contend that centralization is necessary to resolve the split incentives issue, where coordination is necessary (Howarth and Sanstad, 1995; Sorrell et al., 2004), particularly if decision makers are faced with multiple recommendations. Moreover, split incentives and information failure can occur simultaneously when part of an organization does not want to share information about energy efficient projects because it will not benefit from the savings.

Third, the traditional economic view of top management is that they decide between alternative courses of action based on maximizing the long-term market value of the firm, defined as "the sum of the values of *all* financial claims on the firm—debt, warrants, and preferred stock, as well as equity" (Jensen, 2010: 32). We argue that this means that they are best positioned to make choices about energy efficiency. In the context of energy efficiency, top managers will therefore emphasize the savings realized. Such a holistic "savings-oriented" approach might not be adopted by others, such as operations or facilities managers who might focus more on the technical feasibility of the recommendation. We therefore propose the following hypothesis:

Hypothesis 1: *Top Management involvement in energy efficiency assessments facilitates the adoption of a higher proportion of savings than involvement by other employees.*

The literature has shown that managers apply high discount rates to the evaluation of energy efficiency investments (Ruderman et al., 1987; Ross, 1986; Howarth and Sanstad, 1995) and describe managers' preference for recommendations with rapid payback rather than long-term benefit (DeCanio, 1993; Sorrell et al., 2000). Here we argue that such preference might not be true for top managers as compared to other managers and employees. We contend that because top managers are in charge of the strategic orientation of the firm which aims at sustaining competitive advantage through analysis, organizational planning and long-term vision (Porter, 1985), they will be more likely to adopt innovations that not only have higher savings but that also improve long-term profitability. This is particularly true in private small and medium-sized enterprises where top managers are associated with the long-term success of the company (Shrader et al., 1989), and engage in more long term planning (Naffziger and Kuratko, 1991; Stonehouse and Pemberton, 2002; Kraus et al., 2006). Furthermore, top managers have a broader view of the organization and the resources available, as well as more control over these resources. Top managers can reallocate resources, while other employees are more likely to perceive resource constraints as given and binding. We therefore hypothesize the following:

Hypothesis 2: *Top Management involvement in energy efficiency assessments facilitates the adoption of recommendations with longer payback periods than involvement by other employees.*

Prior research has suggested that resource availability determines, to a significant extent, the level of adoption of innovations (Rogers, 1983; Rogers and Agarwala-Rogers, 1976). Because top managers have control over resources within the organization, they should be less likely to reject on account of economic and organizational reasons. However, top managers are usually less familiar than, for example, operational managers are with the operational implications of a specific innovation, especially if their background is in general management or finance rather than operations management (Hambrick and Mason, 1984). Conversely, operations managers are more likely to confront resource constraints and split incentives problems, so they are likely to focus instead on the technical feasibility and operational consequences of the innovation. We therefore hypothesize that:

Hypothesis 3: *Top management involvement in energy efficiency assessments is associated with higher rejection due to operational reasons relative to organizational or economic reasons than is the case for other employees.*

4. Data and Measures

To test our hypotheses, we use data from the IAC program that provides free energy assessments to eligible small and medium sized manufacturing firms. The assessments identify potential savings from energy efficiency improvements, waste minimization and pollution prevention, and productivity improvement. Assessments are conducted by local teams of engineering faculty and students from a network of participating universities. Over 50 universities have participated at various times since it started in 1976. In fiscal year 2010, the budget for the IAC program was $3.87 million and 386 assessments were performed (DOE 2011).

Firms must meet multiple criteria in order to be eligible for the free assessments, including whether the plant's products are within SIC codes 20 through 39, whether the plant is within 150 miles of the host campus, whether the firm has gross annual sales below $100 million, whether the firm has less than 500 employees, whether the firm has annual energy bills between $100,000 and $2 million and whether the firm has no professional in-house staff to perform the assessment (Muller et al., 2004).

The typical assessment process starts either with the IAC contacting prospective firms or with the firms getting in touch with the IAC indicating interest in an assessment. The first step is to gather data on the firm's present energy usage. This is followed by a plant visit during which the IAC team collects operational data, interviews the plant management and identifies some initial improvement opportunities. Based on the visit and data analysis the IAC team identifies recommendations in a written report to the firm. The IAC tracks the adoption status of the recommendations for a period of two years and uploads information on the assessments, the recommendations and their adoption status to the IAC database.

4.1 Data Used for the Analysis

We constructed a unique database from three sources. First, we drew on the publicly available IAC data maintained by the Center for Advanced Energy Systems (CAES) at Rutgers University. We use the data from 175 assessments that cover 1,391 recommendations made by the SDSU IAC during 2000-2008. The SDSU IAC is a well-established center that has been in operation since the early years of the IAC program. This data includes plant level variables such as plant size, annual sales, number of employees, number of recommendations in the assessment, annual energy usage, annual energy cost, etc. It also includes recommendation-level variables such as initial implementation costs, payback in years, annual energy saving potential, implementation status, etc.

We supplemented this public data with additional information collected by the IAC program and shared by CAES at Rutgers University on the reasons cited for not adopting recommendations. Finally, we worked with SDSU to obtain information on the managerial involvement in the assessment within each firm. During the IAC audits, the firm assigns a contact person to the assessment team. This person could be an executive manager (e.g., President) or a knowledgeable employee or manager directly related to the manufacturing process (e.g., Manufacturing Engineer). The assigned person is usually involved during the entire assessment process, providing pre-assessment information, joining the IAC team during the assessment in the facility, receiving the report, participating in the decision-making process to some extent, and providing the implementation status and reasons for rejection in the follow-up call. To the best of our knowledge, this dataset is unique as it relates the specifics of the recommendations and the firms to the position of the actual managers who led the assessment and implementation efforts.

Overall, our dataset includes 1,391 recommendations in 175 assessments between the years 2000 and 2008. We exclude 12 recommendations that have payback longer than 7 years, as these are outliers. The average assessment has 7.88 recommendations. Of the remaining 1,379 recommendations, 900 were rejected and 479 adopted. The average payback period is 1.07 years, the average implementation cost is $44,602 and the average annual saving is $38,929. The average annual firm's sales were $42.65 million, average plant size was 506,285 square feet and the average firm had 202 employees. Table 1 provides descriptive statistics, and Table 2 provides correlations.

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Insert Tables 1 and 2 here

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4.2 Measures Used for the Analysis

4.2.1 Main Variables Used

Proportion of Savings Adopted – This is the total annual savings of all recommendations in an assessment which are adopted as a proportion of total annual savings across all recommendations in that assessment. It is calculated as $B_j = \sum_{i\, \epsilon\, \text{implemented}} b_{ij} / \sum_i b_{ij}$, where b_{ij} is the expected annual savings for recommendation i in assessment j.

Proportion of Costs Adopted – This is the total implementation costs of all recommendations in an assessment which are adopted as a proportion of total implementation costs across all recommendations in that assessment. It is calculated as $C_j = \sum_{i\, \epsilon\, \text{implemented}} c_{ij} / \sum_i c_{ij}$, where c_{ij} is the expected implementation costs for recommendation i in assessment j.

Average Payback of Implemented Recommendations – Payback is measured in years and calculated in the DOE database as implementation cost divided by annual savings for each recommendation. We define average payback per assessment as $I_j = (\sum_{i\,\epsilon\,\text{implemented}} PB_{ij}) / M_j$, where $PB_{ij} = c_{ij} / b_{ij}$ is the payback of recommendation i in assessment j and M_j is the number of recommendations adopted in assessment j. (Note: We deliberately use the unweighted average payback as the analysis with this variable treats each recommendation as equivalent.)

Reasons for Rejection – In the follow-up phone calls each IAC collects information on why recommendations were not implemented and classifies the reasons into 22 categories (see Table 3). In our case, the same person conducted all the follow-up phone calls and the coding , enhancing consistency. We further classify the rejection reasons into four distinct groups. The first group includes recommendations that were rejected for economic or financial reasons. Those in the second group were rejected for organizational reasons, such as personnel or bureaucracy. Those in the third group were rejected for operational reasons, such as manufacturing, equipment, material or process-related concerns. The fourth group includes the remaining reasons. Of the 900 recommendations that were rejected, 256 were classified as rejected for economic reasons, 306 for organizational reasons, 223 for operational reasons, and 115 as rejected for other reasons. Members of the IAC team and two authors of this study did the classification into the four groups. We use a categorical variable with values of 1, 2, 3 and 4 to represent these four groups. The 22 original rejection categories and our classification into the four distinct groups are provided in Table 3.

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Insert Table 3 here

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Top Management – We use an indicator variable with a value of 1 if the manager leading the assessment for the firm belongs to top management and 0 otherwise. We use the job description of the person leading the assessment to classify the person as belonging to top management or not. The four authors of this study conducted this classification independently. The kappa statistic of inter-rater agreement is 0.69, which is quite high; Landis and Koch (1977) suggest that kappa statistic scores between 0.61 and 0.80 represent substantial agreement. Job descriptions on which the raters disagreed were discussed again and a conservative classification approach was adopted, only coding a person as top management if there was consensus. Table A1 in the Appendix shows the full categorization. We also used different versions of the top management variable by adding or removing select job descriptions; our results are robust to alternative classifications. Overall 29 out of 175 job descriptions included in our analyses were identified as indicating top management.

4.2.2 Variables Used as Controls

Total Number of Recommendations in an Assessment – This variable N_j represents the total number of recommendations made in an assessment.

Average Payback for Assessments (Weighted by Savings) – The dependent variables represent measures of adoption. It is possible that adoption rates are higher for assessments with more profitable recommendations, so we need to control for the average profitability of the entire assessment. We use the average payback of recommendations in an assessment, weighted by savings, calculated as $A_j = (\sum_i b_{ij} * PB_{ij})/(N_j * \sum_i b_{ij})$, where b_{ij} represents the expected annual savings for recommendation i in assessment j and PB_{ij} is the payback of recommendation i in assessment j. A lower score indicates that the assessment has more profitable recommendations.

Energy Costs / Sales – This variable E_j represents the total energy costs for a firm as a fraction of its total revenues. This measure of energy intensity controls for whether energy forms a significant portion of the firm's costs.

Economic Characteristics of a Recommendation – We follow Anderson and Newell (2004) and use payback and then costs and savings to control for the economic characteristics of a recommendation. We use the logarithm of payback of the recommendation, $\ln(\text{Payback}_{ij})$, for recommendation i in assessment j, in one set of models. Similarly, we use $\ln(\text{Cost}_{ij})$ and $\ln(\text{Saving}_{ij})$ as controls in another set of models. The logarithmic form yields superior fit but the linear form provides similar results.

Type of a Recommendation – The DOE classifies the various recommendations made over the history of the IAC program by the Assessment Recommendation Code (ARC) into 25 major categories and over 600 sub-categories. The ARC is a 5-digit code, the details of which are available in "The DOE Industrial Assessment Database Manual" (Muller et al., 2004). We include indicator variables to identify each recommendation as belonging to one of 25 mutually exclusive major categories of recommendations based on the first two digits of the ARC.

Year of Assessment – We use indicator variables for the year the assessment was done.

SIC Level Control – We use indicator variables to identify the firm's two-digit SIC code

Other Firm Level Controls – We use the sales of the firm, the number of employees and the plant area as additional controls.

5. **Methodology**

In this section we discuss our methodology. All analyses were done using STATA version 10.1. To test our first hypothesis, which states that top management involvement facilitates adoption of a larger proportion of savings in an assessment, we estimate the following model using OLS:

$$B_j = \alpha + C_j*\beta + \mathbf{U_j*\gamma} + A_j*\varsigma + E_j*\eta + N_j*\lambda + S_j*\varphi + \mathbf{R_j}*\omega + \varepsilon_j \quad (1)$$

where B_j is the proportion of savings in assessment j corresponding to recommendations which are adopted; C_j is the proportion of costs in assessment j which are adopted; $\mathbf{U_j}$ is a vector which includes variables to identify top management and related interaction terms for each assessment j; A_j represents the average payback for assessment j (weighted by savings); E_j represents the energy costs as a fraction of sales for the firm in assessment j; N_j represents the number of recommendations in assessment j; S_j represents the sales of firm j; the matrix $\mathbf{R}_j$ includes controls for the number of employees, plant area, two digit SIC codes, and year of assessment. ε_j represents the error terms.

We evaluate three versions of model (1), using different versions for the variables related to top management in vector $\mathbf{U_j}$**.** The first model only includes the indicator variable U_j to identify whether top management led the audit effort for assessment j. Because the effect of top management may depend on the firm's energy intensity or size, we include the corresponding interaction effects in the second and third models. The results are shown in Table 4.

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Insert Table 4 here

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Model (1) treats the proportion of costs adopted as exogenous, but this need not be so as it is determined jointly with the proportion of savings adopted. OLS may not be appropriate in such contexts, so we estimate the following simultaneous equations model (Wooldridge 2002):

$$B_j = \alpha_1 + C_j*\beta_1 + \mathbf{U_j*\gamma_1} + A_j*\varsigma_1 + E_j*\eta_1 + N_j*\lambda_1 + S_j*\varphi_1 + \mathbf{R_j}*\omega_1 + \varepsilon_{j1} \quad (2a)$$

$$C_j = \alpha_2 + B_j*\theta_2 + \mathbf{U_j*\gamma_2} + A_j*\varsigma_2 + E_j*\eta_2 + N_j*\lambda_2 + \mathbf{R_j}*\omega_2 + \varepsilon_{j2} \quad (2b)$$

We do not include sales and the number of employees in (2b) to ensure that the model is identified. We again evaluate three versions of model (2), as shown in Table 5a and 5b.

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Insert Tables 5a-b here

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Our second hypothesis predicts that top management adopts recommendations with longer payback as compared to other employees. We evaluate this hypothesis using two approaches. First, we divide the assessments into two groups based on whether the assessments were led by top management or not. For each assessment we compute the average payback of all recommendations and the average payback of implemented recommendations, and then perform t-tests on the differences between these averages. The results are shown in Table 6, and indicate that recommendations made to top managers do not have significantly longer payback, while the recommendations adopted by top managers do.

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Insert Table 6 here

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Second, we estimate the following model using OLS:

$$I_j = \alpha + U_j*\gamma + E_j*\eta + N_j*\lambda + S_j*\varphi + \mathbf{R_j}*\omega + \varepsilon_j \quad (4)$$

where I_j is the average payback of implemented recommendations in assessment j, and the rest are as defined in (1). The results are shown in Table 7.

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Insert Table 7 here

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Our third hypothesis predicts that top management will be less likely to reject recommendations for economic or organizational reasons than for operational reasons, relative to other employees. Consequently we restrict our analyses to recommendations that were not adopted. We estimate the following multinomial logit model for the four categories of rejection reasons:

$$Z_{ijk}^{*} = \alpha + \mathbf{M}_{ij}*\boldsymbol{\beta}_{\mathbf{k}} + U_j*\gamma_k + E_j*\eta_k + N_j*\lambda_k + S_j*\varphi_k + SP_{ij}*\chi_k + \mathbf{R}_{\mathbf{ij}}*\omega_k + \varepsilon_{ijk} \quad (5)$$

where $\mathbf{M}_{ij}$ is the vector of financial variables (ln($Payback_{ij}$), or ln($Cost_{ij}$) and ln($Savings_{ij}$)) for recommendation i in assessment j; SP_{ij} is the serial position of recommendation i in assessment j; and the remaining terms are as defined in (1). ε_{ijk} represents the error terms. Again following Anderson and Newell (2004), we estimate a "Payback" model and a "Cost-Benefit" model. As usual in multinomial models, we only observe the chosen (rejection) category, Z_{ijk}, which is assumed to be the utility-maximizing, or, in our case, most accurate choice.

We evaluate two versions each of the "Payback" and "Cost-Benefit" models in (5), first using rejection for economic reasons as the comparison group and then rejection for organizational reasons. The results are shown in Table 8.

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Insert Table 8 here

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6. Results

In this section, we present our main results related to our three hypotheses, draw implications and discuss limitations and alternative explanations

Hypothesis 1 argues that top management facilitates the adoption of a higher proportion of savings as compared to other employees in an organization. We observe that the coefficient of the top management variable in model (1) of Table 4 is positive and significant at $p<0.05$. Similarly the coefficient of the top management variable in model (1) of Table 5a for equation (2a) is positive and significant at $p<0.01$. These results provide support for Hypothesis 1. To better understand whether the impact of top management is moderated by energy costs or overall sales we refer to models (2) and (3) in Table 4 and Table 5a. These models add interaction terms to model (1). The F-test to compare the main-effects model with the interactive terms model (Freidrich 1982) is only significant for model (3) of Table 4, the interaction with sales. We then test for the significance of the slope term of that interaction, as suggested by Jaccard et al. (1991), and find that it is not significant. This indicates that top management influence on the adoption of a higher proportion of savings is not moderated by energy cost or sales. Further, if we consider an average assessment in model (1) in Table 4, then the presence of top management increases the proportion of savings adopted by 10% (percentage points). In Table 5a for model (1), the presence of top management increases the proportion of savings adopted by 9.4% (percentage points). Given that the average proportion of savings adopted across all assessments is 28.0%, our results indicate that the presence of top management increases the proportion of savings adopted by over 33% in relative terms. We also observe that the coefficients of the top management variable are not significant at $p<0.05$ in any of the models in Table 5b for equation (2b). This suggests that top management involvement does not increase the focus on the overall costs as it does for the overall savings. The interaction effects in Table 5b are also not significant. (As an additional check we evaluated model (1) without the variable C_j and our results are similar.) Overall, these results provide robust support for the impact of top management in the adoption of energy saving initiatives. A possible concern is that top management is more likely to be involved in assessments when the firm has high focus on energy efficiency. If true, then the firm would already have adopted easy initiatives and the IAC team would only find recommendations with lower rates of return. However, from Table 6a, we see that the average payback across all recommendations made to top management and to other employees is not significantly different. Our results therefore contradict prior work that argues that top management involvement does not influence adoption of process-based innovations.

However, the earlier results are based on analysis of individual innovations in contrast to our analyses that are done at the assessment level. We did also analyze adoption decisions at the recommendation level, using a logit model similar to the one used by Anderson and Newell (2004), with a vector of variables to identify top management and related interaction terms for each recommendation. The results in Table 9 show that the variables for top management are not significant in any of the six models. Next to identify the presence of interaction effects, we adopt the approach indicated in Ai and Norton (2003) who point out that, unlike linear models, in non-linear models presence of significant interaction terms does not indicate presence of significant interaction effects. We find that the interaction effect is significant at $p<0.05$ only in model (6). Overall the results from our logit models are in line with prior literature which finds that top management involvement does not influence adoption of process based innovations when these innovations are considered individually.

For Hypothesis 2, which argues that top management facilitates adoption of energy efficiency initiatives by implementing recommendations with longer paybacks as compared to other managers, we first refer to Table 6. From Table 6 we infer that the average payback of implemented recommendations is longer for top management and significant at $p<0.01$. Next, Table 7 shows that the coefficient of top management is positive and significant at $p<0.1$. This indicates that presence of top management results in longer average payback of implemented recommendations (0.9375 years) as compared to other managers who on average adopt recommendations with a much quicker payback (0.5946 years). Overall our results indicate that top management is willing to wait 57.7% longer than other managers to recoup the initial costs of implementing a recommendation

With respect to Hypotheses 3, which seeks to examine the impact of top management on the reasons for rejection, we refer to Table 8. We observe that the coefficients for top management for rejection due to operational reasons (as compared to economic and organizational reasons) are positive and significant at $p<0.1$ in all four models in Table 8. Further, in model (4) in Table 8 the probability of rejection for operational reasons increases by over 38%, from 0.447 when top management is not involved to 0.629 when top management leads the assessment.

In summary, our results confirm our hypotheses. First, we find that involvement of top management enables the adoption of a higher proportion of savings than does that of other managers. Second, we find that top management is willing to adopt recommendations with longer paybacks. Third, we find that top management is more likely to reject recommendations for operational rather than economic or organizational reasons, as compared to other employees.

7. Discussion and Conclusion

This paper investigates the role of top management in the adoption of energy efficiency initiatives. Our results show that the involvement of top management in energy efficiency assessments has a significant impact on the adoption of energy efficiency improvement. The presence of top management increases the proportion of savings adopted by over 33% and when top management is involved, the average payback of the adopted recommendations is 34.3% longer. We also find that top management tends to reject recommendations less for economic and organizational reasons than for operational reasons, relative to other employees. These results are in contrast with prior analyses conducted at the individual innovation level, which shows that top management has no significant impact on the number of innovations adopted.

These results have significant implications for the IAC program, which seeks to enhance the adoption of energy saving initiatives in small and medium-sized firms. Our results suggest that the IAC should actively seek to ensure that top management of the firm leads the energy assessment effort and is involved from the beginning of the process. Currently the DOE suggests that the IACs provide recommendations which have less than two year payback. There is no clear justification for this high threshold. Our results suggest that the IACs may consider recommendations with longer payback, especially if the top management of a firm leads the energy efficiency assessment effort. Furthermore when evaluating the success of its program, the IAC should favor metrics based on the total savings adopted by the firm rather than the number of recommendations adopted.

Another implication of our results is that the IACs should try to pre-emptively address potential concerns related to operational factors, especially when recommendations are made to top management. Scholars have shown that cross-functional communication is an important precursor to innovation (Hambrick and Mason, 1984; Shrivastava and Souder, 1987; Rothwell and Zegveld, 1985). The IAC program should therefore also encourage the involvement of operations managers along with top management. Such cross-functional teams should positively influence the adoption of recommendations.

Our analysis is not without limitations. First, the data cover only assessments of Southern California plants. Further research should expand the analyses to other states to assess the role of external environmental factors such as state regulations and market conditions on the adoption of energy efficiency recommendations. Second, while we were able to identify the involvement of top management in the energy efficiency assessment team, we did not have access to information about the demographics of top management. Factors such as top management age, gender, marital status, education, employment status, and political orientation have been shown to play an important role on firm performance (Hambrick and Mason, 1984; Michel and Hambrick, 1992) and on the adoption of environmental practices (Torgler and Garcia-Valinas, 2007; Musteen et al., 2006; Slater and and Dixon-Fowler, 2010) and this might also be the case for adoption of energy efficiency practices.

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Table 1: Summary Statistics

Variable	Mean	Std Dev	Min	Max	N
Implementation Status (1= Yes)	0.347	0.476	0	1	1,379
Payback (in years)	1.067	1.114	0	6.956	1,379
Implementation Cost (in US$)	44,602	206,695	0	3,037,200	1,379
Annual Saving (in US$/year)	38,929	166,055	83	3,022,214	1,379
Serial Position of a Recommendation	5.11	3.31	1	20	1,379
Rejected for Economic Reasons (1= Yes)	0.284	0.451	0	1	900
Rejected for Organizational Reasons (1= Yes)	0.340	0.474	0	1	900
Rejected for Operational Reasons (1= Yes)	0.248	0.432	0	1	900
Top Management	0.166	0.373	0	1	175
Number of Recommendations	7.88	2.999	3	20	175
Sales (in US$)	42,650,921	86,995,672	0*	931,500,000	175
Plant Area (in sq. ft.)	506,285	3,953,284	40	52,272,000	175
Employees	202	242	0*	1,900	175

Note: Statistics are based on 1379 recommendations, representing 175 assessments. (Of these, 479 recommendations were implemented.)

* The data from IAC has value 0 for: 1) Sales (8 Assessments) and 2) Employees (1 Assessment). Our results are valid even if we exclude these data from our analyses.

Table 2: Correlations for Select Variables used in the Analyses

(Pairwise Correlations with Significance at 0.05 levels)

	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	ln(Payback)	1.0000											
(2)	ln(Saving)	0.1425*	1.0000										
(3)	ln(Cost)	0.8989*	0.5175*	1.0000									
(4)	Top Management	-0.0113	-0.1183*	-0.0586*	1.0000								
(5)	Top Management * Number of Recommendations	-0.0275	-0.1064*	-0.0682*	0.9264*	1.0000							
(6)	Top Management * Energy Costs/Sales	0.0398	-0.0727*	0.0094	0.2727*	0.1911*	1.0000						
(7)	Top Management * Sales (in millions)	-0.0026	-0.0766*	-0.0375	0.7315*	0.6505*	0.0839*	1.0000					
(8)	Energy Costs / Sales	-0.0108	0.1363*	0.0444	-0.1256*	-0.1112*	-0.0448	-0.0161	1.0000				
(9)	Serial Position of a Recommendation	0.033	-0.0116	0.0257	0.0827*	0.0231	0.8318*	-0.0428	-0.0837*	1.0000			
(10)	Number of Recommendations	-0.0455	-0.1581*	-0.0872*	0.0005	0.0005	0.0001	0.0004	-0.0006	0.0005	1.0000		
(11)	Employees	-0.0727*	0.1956*	0.0082	-0.0469	0.1012*	-0.0741*	-0.0620*	0.2549*	-0.0219	0.001	1.0000	
(12)	Plant Area	-0.0145	0.0309	0.0039	-0.0426	-0.0412	-0.0097	-0.029	-0.0091	0.1193*	0.0001	-0.0476	1.0000

Table 3: Rejection Reason Categories

Code	Reason, using 22 original categories	Group
N1	Unsuitable return on investment	Economic (1)
N2	Too expensive initially	
N3	Cash flow prevents implementation	
N10	Material restrictions	Operational (2)
N4	Unacceptable operating changes	
N6	Process and/or equipment changes	
N7	Facility change	
N9	Production schedule changes	
N15	Not worthwhile	
N16	Disagree	
N5	Impractical	
N18	Suspected risk or problem with equip. or product	
N11	Bureaucratic restrictions	Organizational (3)
N14	Lack of staff for analysis and/or implementation	
N8	Personnel changes	
N17	Risk or inconvenience to personnel	
N22	Other	Other (4)
N12	To be implemented after 2 years – discontinued	
N13	Considering – discontinued	
N19	Rejected after implementation failed	
N20	Unknown	
N21	Could not contact plant	

Table 4: Estimation Results for OLS Model for Proportion of Savings Implemented

Dependent Variable: Proportion of Savings Implemented	(1)	(2)	(3)
Proportion of Cost Implemented	0.728 ***	0.727 ***	0.745 ***
	(0.05)	(0.05)	(0.05)
Top Management	0.100 **	0.092 *	0.186 **
	(0.05)	(0.05)	(0.08)
Top Management * Energy Costs/Sales		0.201	
		(0.20)	
Top Management * Sales (in millions)			-0.004
			(0.00)
Energy Costs / Sales	-0.114	-0.275	-0.156 *
	(0.09)	(0.20)	(0.09)
Sales (in million US$)	0.00001	0.00002	-0.00002
	(0.0003)	(0.0003)	(0.0003)
Average Payback for Assessments - (Weighted by Savings)	-0.208 **	-0.211 **	-0.231 **
	(0.10)	(0.10)	(0.10)
Number of Recommendations	-0.010	-0.010	-0.011
	(0.01)	(0.01)	(0.01)
Employees (in thousands)	-0.024	-0.027	0.011
	(0.11)	(0.11)	(0.11)
Plant Area (in million sq. ft.)	0.0018	0.0021	0.0021
	(0.002)	(0.002)	(0.002)
Additional Controls Included			
SIC	Yes	Yes	Yes
Year	Yes	Yes	Yes
R-Square	0.74 ***	0.74 ***	0.75 ***
Adjusted R-Square	0.67	0.67	0.68
Number of Observations	165	165	165

standard errors are in parantheses ; * p<0.1, ** p<0.05, *** p<0.01

Table 5a: Estimation Results for SEM Model for Proportion of Savings Implemented and Proportion of Costs Implemented – Equation (2a) for Proportion of Savings Implemented

Dependent Variable: Proportion of Savings Implemented			
	(1)	(2)	(3)
Proportion of Cost Implemented	0.846 ***	0.867 ***	0.893 ***
	(0.31)	(0.30)	(0.32)
Top Management	0.094 ***	0.087 **	0.200 ***
	(0.04)	(0.04)	(0.06)
Top Management * Energy Costs/Sales		0.168	
		(0.36)	
Top Management * Sales (in millions)			-0.005 *
			(0.00)
Energy Costs / Sales	-0.089	-0.220	-0.137
	(0.15)	(0.33)	(0.15)
Sales (in million US$)	0.00001	0.00001	-0.00004
	(0.0001)	(0.0001)	(0.0001)
Average Payback for Assessments - (Weighted by Savings)	-0.168	-0.163	-0.188 *
	(0.12)	(0.12)	(0.11)
Number of Recommendations	-0.007	-0.007	-0.008
	(0.01)	(0.01)	(0.01)
Employees (in thousands)	-0.011	-0.010	0.038
	(0.09)	(0.10)	(0.11)
Additional Controls Included			
SIC	Yes	Yes	Yes
Year	Yes	Yes	Yes
R-Square - 1st Equation	0.726 ***	0.722 ***	0.729 ***
Number of Observations	165	165	165

standard errors are in parantheses ; * p<0.1, ** p<0.05, *** p<0.01

Table 5b: Estimation Results for SEM Model for Proportion of Savings Implemented and Proportion of Costs Implemented – Equation (2b) for Proportion of Costs Implemented

Dependent Variable: Proportion of Cost Implemented			
	(1)	(2)	(3)
Proportion of Savings Implemented	1.088	1.079 *	1.403 *
	(0.67)	(0.65)	(0.78)
Top Management	-0.098	-0.091	-0.258 *
	(0.10)	(0.09)	(0.13)
Top Management * Energy Costs/Sales		-0.166	
		(0.47)	
Top Management * Sales (in millions)			0.006 **
			(0.00)
Energy Costs / Sales	0.082	0.212	0.223
	(0.23)	(0.50)	(0.28)
Average Payback for Assessments - (Weighted by Savings)	0.156	0.154	0.338
	(0.33)	(0.32)	(0.38)
Number of Recommendations	0.006	0.006	0.016
	(0.02)	(0.02)	(0.02)
Plant Area (in million sq. ft.)	0.001	0.001	-0.004
	(0.01)	(0.01)	(0.01)
Additional Controls Included			
SIC	Yes	Yes	Yes
Year	Yes	Yes	Yes
R-Square - 2nd Equation	0.701	0.703	0.567
Number of Observations	165	165	165

standard errors are in parantheses ; * p<0.1, ** p<0.05, *** p<0.01

Table 6: Differences in Average Payback between Top Management and Others

	ALL Recommendations		Implemented Recommendations	
	Top Management	Other	Top Management	Other
Number of Observations	29	146	29	146
Average Payback	1.236	1.095	0.951	0.584
Standard Error	0.155	0.042	0.186	0.052
Difference in Mean	0.141		0.367***	
t statistic	1.21		2.56	
Degrees of Freedom	173		173	

* p<0.1, ** p<0.05, *** p<0.01

Table 7: Estimation Results for OLS Model for Average Payback of Implemented Recommendations

	Dependent Variable: Average Payback of Implemented Recommendations
Top Management	0.343 *
	(0.17)
Energy Costs / Sales	1.761 **
	(0.69)
Number of Recommendations	0.010
	(0.02)
Sales (in million US$)	-0.002 **
	(0.00)
Employees (in thousands)	0.515
	(0.38)
Plant Area (in million sq. ft.)	0.031 ***
	(0.01)
Additional Controls Included	
SIC	Yes
Year	Yes
R-Square	0.406 ***
Adjusted R-Square	0.268
Number of Observations	165

standard errors are in parantheses ; * p<0.1, ** p<0.05, *** p<0.01

Table 8: Estimation Results for Multinomial Logit Model for Choice of Reasons for Rejection

Dependent Variable: Rejection Reason	Economic Reasons as Base for Comparison		Organizational Reasons as Base for Comparison	
	Payback Model **(1)**	Cost-Benefit Model **(2)**	Payback Model **(3)**	Cost-Benefit Model **(4)**
Rejection Reason = Operational Reasons				
ln(Payback)	-0.241 ***		-0.010	
	(0.07)		(0.03)	
ln(Saving)		0.323 **		0.204 *
		(0.13)		(0.11)
ln(Cost)		-0.327 ***		-0.021
		(0.10)		(0.04)
Top Management	0.638 *	0.659 *	0.750 **	0.852 **
	(0.38)	(0.38)	(0.38)	(0.39)
Employees	-0.001	-0.001	0.002 **	0.002 *
	(0.00)	(0.00)	(0.00)	(0.00)
Energy Costs / Sales	-4.632	-4.746	-0.748	-1.074
	(4.45)	(4.60)	(3.07)	(3.00)
Serial Position of Recommendation	-0.048	-0.044	-0.123 **	-0.075
	(0.06)	(0.07)	(0.05)	(0.06)
Number of Recommendations	-0.056	-0.059	-0.073	-0.103
	(0.06)	(0.07)	(0.07)	(0.08)
Additional Controls Included				
Recommendation Types	Yes	Yes	Yes	Yes
Sales	Yes	Yes	Yes	Yes
SIC	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Psuedo R-Square	0.21	0.21	0.21	0.21
Log-PseudoLikelihood	-843	-840	-843	-840
Number of Observations	800	800	800	800

standard errors are in parantheses ; * p<0.1, ** p<0.05, *** p<0.01

Note: Estimation results for rejection on account of economic, organizational and other reasons have been omitted to facilitate presentation of results.

Table 9: Estimation Results for Logit Model for Adoption of Recommendations

Dependent Variable: Adopted (equals 1 if recommendation is implemented, 0 otherwise)						
	Payback Models			**Cost-Benefit Models**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ln(Payback)	-0.093 ***	-0.094 ***	-0.092 ***			
	(0.02)	(0.02)	(0.02)			
ln(Saving)				0.031	0.040	0.021
				(0.07)	(0.07)	(0.07)
ln(Cost)				-0.159 ***	-0.161 ***	-0.157 ***
				(0.03)	(0.03)	(0.03)
Top Management	0.253	0.134	-0.280	0.217	0.105	-0.335
	(0.23)	(0.25)	(0.31)	(0.23)	(0.25)	(0.32)
Top Management * Energy Costs/Sales		3.009 **			2.908 *	
		(1.52)			(1.56)	
Top Management * Sales (in millions)			0.028 **			0.029 **
			(0.01)			(0.01)
Energy Costs / Sales	0.930	-1.277	1.233	0.911	-1.199	1.221
	(0.93)	(1.35)	(0.97)	(0.94)	(1.40)	(0.98)
Sales (in million US$)	-0.00493 **	-0.00486 **	-0.00536 **	-0.00481 **	-0.00475 *	-0.00521 **
	(0.0024)	(0.0025)	(0.0024)	(0.0024)	(0.0025)	(0.0023)
Number of Recommendations	-0.014	-0.011	-0.013	-0.012	-0.009	-0.010
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Employees (in thousands)	0.001 *	0.001 *	0.001 *	0.001 **	0.001 *	0.001 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Additional Controls Included						
SIC	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Psuedo R-Square	0.12	0.12	0.13	0.13	0.13	0.13
Log-PseudoLikelihood	-712.43	-711.27	-708.91	-705.16	-704.11	-701.45
Number of Observations	1243	1243	1243	1243	1243	1243

standard errors are in parantheses ; * p<0.1, ** p<0.05, *** p<0.01

Appendix

Table A1: Top Management Categorization

Job Description	Frequency (recommendation level)	Top Management	Other
Director of Engineering	9		x
Plant Superintendent	7		x
Material Control Manager	10		x
Maintenance Engineer	18		x
Senior Engineer	7		x
Buyer	6		x
Facilities Technician	6		x
Materials Manager	9		x
Purchasing Agent	8		x
President-CEO	5	x	
Chemist	5		x
Facility Project Engineer	5		x
CEO	15	x	
Facilities Supervisor	14		x
Electrical Supervisor	12		x
Manufacturing Engineer	9		x
Wine Maker	9		x
Operations Manager	38		x
V.P. of Operations	55	x	
Energy Manager	17		x
Site Executive	11	x	
V.P. of Engineering	6	x	
Safety Director	10		x
Senior Engineering Manager	6		x
Maintenance/Engineering Manager	18		x
Production Manager	25		x
President-General Manager	7	x	
Facilities Manager	97		x
Plant Facilities Manager	4		x
Executive Vice President	10	x	
Owner	10	x	
Manufacturing Supervisor	10		x
Plant Engineer	37		x
Plant Manager	207		x

Job Description	Frequency (recommendation level)	Top Management	Other
Maintenance Manager	87		x
Project Engineer	21		x
Process Engineer	38		x
V.P. of Manufacturing	33	x	
Quality Control Engineer	9		x
Facility Engineering Manager	26		x
Metallurgist	17		x
General Manager	40		x
Maintenance Supervisor	61		x
Chief Engineer	27		x
Site Manager	8		x
Facility Engineer	4		x
Engineering Manager	46		x
Business Development and Marketing	5		x
Senior Business Analyst	5		x
Production Supervisor	5		x
Manufacturing Engineering Manager	10		x
Senior Facilities Engineer	6		x
Tech Opt Manager	12		x
Director of Operations	15		x
Controller	7		x
Division Facilities Manager	7		x
President	24	x	
Vice President/General Manager	8	x	
Electrical Eng	8		x
Eng tooling mgr	12		x
Director of Manufacturing	13		x
Director of Purchasing	9		x
Senior Plant Manager	7		x
Facilities Secretary	5		x
Manager	6		x
Manufacturing Manager	10		x
Safety and Environmental Compliance Supervisor	5		x
Safety Manager	7		x
Engineer	16		x
Manufacturing Engineering Supervisor	8		x