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Will the Management Structure of Energy Administrators Affect the Achievement of the Electrical Efficiency Mandatory Target for Taiwan Factories?

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Abstract: Since 2014, Taiwan has promoted a 1% annual electricity saving target to promote electrical efficiency efforts. As the industrial sector accounts for approximately 60% of the overall electricity consumption of Taiwan, this sector presents the greatest opportunity for improving Taiwan's overall energy efficiency. Here, the energy audit data of industrial energy users are analyzed via logistic regression to understand the factors impacting their likelihood of achieving the targeted 1% electricity saving. Of the variables under study, the number of employees and the rank of the energy administrator were significantly correlated with the likelihood of reaching the electricity saving target. Within the management structure of the factory, energy users with higher-ranking energy administrators are more likely to achieve the targeted 1% electricity saving. As it is impractical to rapidly increase the number of employees, higher-ranking employees, i.e., factory executives, should be appointed as energy administrators to improve users' electrical efficiency and thus reach the targeted 1% annual electricity saving. Based on the findings of our research, we put forward a point of view that in addition to the introduction of new technologies to improve energy efficiency, it can also be achieved through adjustments to the management structure of energy administration.

Keywords: energy efficiency; energy management; energy administrator; target of 1% electricity saving; energy audit; energy efficiency policy programs

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1. Introduction

Taiwan is an island that is located on a seismic area and lacks self-generated energy. The Taiwanese government is currently promoting a nuclear power plant abolition policy. Approximately 98% of its energy use relies on imports, according to the Bureau of Energy [1]. However, drastic changes to the energy supply are difficult to implement because energy structure cannot be adjusted in a short time. Rather, to reduce energy consumption, efforts must be made by the Taiwanese government to reduce demand and improve energy efficiency. The industrial sector accounts for the highest proportion (50%) of energy use among all sectors and thus represents the greatest opportunity for improvement.

In accordance with the 2014 energy policy implemented by the Taiwanese government, energy users are required to set a target of 1% electricity saving. To assist the Taiwanese government in formulating energy efficiency policies, this work, therefore, aims to clarify the factors affecting energy users to help them achieve the electricity saving target.

2. Energy Consumption of Taiwan's Industrial Sector and Target of 1% Electricity Saving

2.1. Taiwan's Energy and Electricity Consumption Status

In terms of energy usage, the industrial sector accounts for the greatest proportion of energy consumption in Taiwan, followed by the transportation, residential, and service sectors, accounting for approximately 50%, 25%, 12%, and 11% of the overall energy consumption, respectively, as summarized in Figure 1 [1]. In terms of electricity usage, the industrial sector accounts for the highest proportion (60%) of electricity usage among all sectors, followed by the service and residential sectors, which each account for approximately 19% of the overall electricity consumption, as shown in Figure 2 [1]. Improving the energy efficiency of the industrial sector thus presents the greatest opportunity for reducing Taiwan's overall energy consumption.

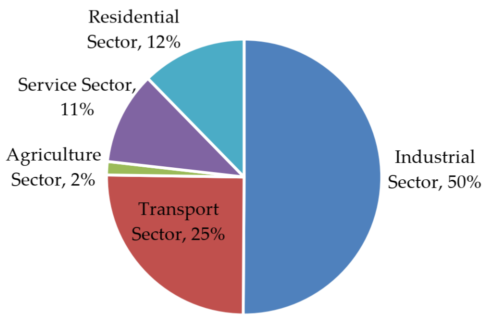

Figure 1. Share of energy consumption in various sectors in Taiwan [1].

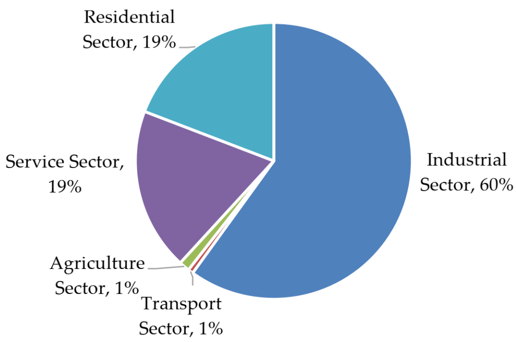

Figure 2. Share of electricity consumption by various sectors in Taiwan [1].

2.2. Management of Taiwanese Energy Users and Target of 1% Electricity Saving

According to the Energy Administration Act (EAA), all factories and business premises whose energy usage meets one of the following criteria shall be regulated as energy users by the competent authority [2]:

1. The annual consumption of coal >6000 metric tons;
2. The annual consumption of fuel oil >6000 kiloliters;
3. The annual consumption of natural gas >10 million cubic meters;
4. The contract capacity of electricity >800 kW.

Further, Article 9 of the Energy Administration Act requires each energy user to establish an energy audit system and set energy efficiency objectives. Article 12 of the EAA requires each user to declare their energy consumption, energy management structure, and energy saving plans to the competent authority, thus allowing a better understanding of the energy usage of each user. As of 2020, 3000–3300 energy users have been defined in the industrial sector, most of which have been included by meeting the fourth criteria; these defined energy users account for more than 80% of the electricity consumption of the entire industrial sector [3]. Therefore, the management of energy users via policy can effectively improve the energy efficiency of the industrial sector.

To this end, Taiwan announced a 1% electricity saving target in August 2014 for the above-defined energy users. Accordingly, all energy users were directed to achieve a 1% annual average electricity saving between 2015 and 2019. However, due to considerations of climate change and energy supply conditions, this 1% annual saving target was extended until 2024.

As this target applies to energy users in the industrial sector that may have increased production or expanded plant capacity and thus increased their overall electricity consumption, a clear definition of electricity saving is needed in which the electricity saving refers to the improvement in energy efficiency rather than the direct reducing of the total electricity usage. If a user's electricity consumption increases, they must also propose a corresponding plan to save their electricity usage to achieve the annual average target of a 1% electricity saving. This caveat is necessary to avoid preventing energy users from expanding where necessary to achieve the required target. Thus, the electricity saving is calculated as

$$R_n = \frac{\sum_{i=2015}^{n} S_i}{\sum_{i=2015}^{n} (C_i + S_i)}, \tag{1}$$

where R_n represents the electricity saving rate, S_i represents the electricity saving in year i, and C_i represents the electricity consumption in year i. Thus, the numerator represents the electricity saving and the denominator, comprising the electricity consumption and electricity saving, represents a user's electricity usage before implementing an electricity saving plan. To avoid double-counting, each saving plan is assumed to be implemented for 12 months. The implementation period of the policy is 2015–2024, mainly to avoid single incidents or special emergencies in certain years that may affect energy users' ability to achieve the target of 1% electricity saving.

2.3. Energy Administrators and Energy Saving Plans

According to Article 11 of the EAA, each energy user must appoint a qualified energy administrator responsible for implementing energy-based government regulations and policies [2]. Depending on the importance of energy affairs for each energy user, energy administrators may be supervisors or general staff members selected by the energy user. One administrator is required for most energy users; if the contract capacity exceeds 100,000 kilowatts, more than two energy administrators must be established. Each administrator must undergo training and pass an exam before becoming an energy administrator. As the administrators may encounter mechanical or electrical problems, all energy administrators must have at least a junior college degree and major in science and engineering before taking the examination.

Energy administrators take responsibility for the energy-related affairs of the factory, promote energy saving and carbon reduction of the factory, and act as a bridge between the factory and the government to implement the government's energy policy. Energy administrators were thus the natural choice to assign the challenge of meeting the 1% electricity saving goals.

The promotion of energy saving plans is more suited to project management than operation management. As the development and implementation of energy saving plans involve planning, selecting the targeted equipment or project, estimating the return on investment (ROI) of the project, and evaluating the feasibility, energy administrators are required to have project management skills. The successful implementation of an energy saving plan requires the budgeting of time and resources. In addition, cross-departmental communication and coordination are required to ensure smooth implementation.

3. Literature Review

From the Kyoto Protocol to the Paris Agreement, reducing carbon dioxide emissions is of international concern [4–7]. Accordingly, each country has put forward its nationally determined contribution (NDC), in which its carbon reduction goals are outlined [8–11].

The promotion of the development of renewable energy can help a country to achieve the goal of carbon reduction. Leal-Arcas et al. [12] observed the phenomenon that energy will be consumed near where it is produced and discussed the role of prosumers in the future development of renewable energy. Borowski [13] discussed the advantages and disadvantages of two different models of the European electricity market and analyzed the impact of the models of the electricity market on the development of renewable energy.

On the other hand, improving energy efficiency is another way to achieve carbon reduction goals. According to the International Energy Agency (IEA), improving energy efficiency is the first and most important step in mitigating carbon emissions [14]. Wang et al. [15] suggest improving energy efficiency and developing carbon emissions reduction technology to achieve China's carbon intensity target. As a result, improving energy efficiency via policies and strategies is a major energy research topic. Researchers have mainly aimed to introduce technologies or improve efficiency in the full industrial sector or country scale. For example, Malinauskaite et al. [16] discussed the energy saving potential of efficiency improvements in the industrial sectors of Slovenia and Spain in relation to the revised Energy Efficiency Directive (EED).

Numerous researchers have developed and used models such as the MARKAL/TIMES, 2050 calculator, marginal abatement cost curve (MACC), or forecast industry model to simulate the introduction of novel technologies or policies and predict their energy saving and carbon reduction potential [17–21]. Others have analyzed the energy consumption of a country or industry using energy efficiency indicators. For example, Yan and Su [22] used economic energy efficiency indicators to analyze the energy policies laid out in China's 12th Five-Year Plan and understand their impact on energy consumption and intensity. Similarly, Hille and Lambernd [23] used energy intensity as an indicator to understand the impact of technological changes on energy consumption and the effectiveness of South Korea's National Strategy for Green Growth.

Peng et al. [24] used energy efficiency indicators such as the specific energy consumption (SEC) to evaluate the energy efficiency and carbon reduction effects of the paper industry in China. Similarly, Assawamartbunlue and Luknongbu [25] used the SEC as an indicator of the energy efficiency of the starch industry in Thailand. Lawrence et al. [26] analyzed the SEC of the paper industry in Sweden and examined the use of this indicator to judge the premise and limitations.

Most such studies have involved exploring changes in the energy efficiency of the country or industry being studied and then determining the factors causing these changes. Rather, this work aims to target individual factories, rather than larger sectors, and discuss the factors that affect the energy efficiency. An efficiency analysis at this smaller scale requires more detailed energy efficiency data on the energy usage and efficiency of a factory.

We can collect detailed energy efficiency data to conduct research by case study. Borowski [27] analyzed the PGE capital group and gelatin company, assessing the impact of Industry 4.0 on the production processes in learning organizations for operational efficiency and energy efficiency. Wojdalski et al. [28] analyzed energy efficiency and water efficiency in the case of a gelatin production plant, finding that they can be improved through technological innovation and strengthened management.

Energy audit data also can provide such detailed data, as prior researchers have shown [29–31]. Kluczek and Olszewski [32] used energy audit data to analyze the efficiency of factory utility equipment such as compressed air and lighting. Shen et al. [33] integrated Chinese energy audit practices and found that energy audits help enterprises to improve energy efficiency and improve their energy management structure. Other researchers have used data obtained from energy audits to discuss the energy efficiency of segments of Taiwan's industrial sector, focusing on the energy saving potential and efficiency trends in the cement, textile, and food industries [34–37].

In addition to technical factors, other factors can also improve energy efficiency [38]. Thollander et al. [39] found financial and organizational factors can be driving forces in improving energy efficiency in European foundry industries. Liao [40] discussed energy management methods used in the Japanese industrial sector; the Ministry of Economy, Trade and Industry of Japan has proposed adjustments to the energy management structure to improve the energy efficiency, such as changing the definition of energy users and adjusting the rank of the energy administrator.

In Taiwan, we observe the energy administrator is similar to a project manager and has the role characteristics of the negotiator, liaison, disturbance handler, and resource allocator while promoting the energy savings plan [41]. Increasing the rank of the energy administrators may impact the energy efficiency of energy users. If high-ranking employees are appointed as energy administrators, the energy user may be more effective in promoting energy efficiency, as higher-ranking employees have more control over the budget and thus can promote larger energy savings plans. Larger-scale plans can produce greater savings and thus increase the chance of meeting the targeted saving.

In their evaluation of the energy users in Taiwan that have achieved the 1% target, Pan and Lee [42] classified energy users according to the number of employees, industry, and company capital. They found that facilities with more employees were more likely to achieve the targeted 1% saving. Thus, the number of employees is likely to affect whether energy users meet the electricity saving target.

This work, therefore, aims to explore the factors affecting the energy efficiency of energy users in Taiwan's industrial sector from the perspective of the energy users' management. To do so, according to the abovementioned literature, this work proposes four hypotheses to clarify the factors affecting energy users' ability to achieve the target of 1% electricity saving.

4. Materials and Methods

4.1. Factors Influencing the Energy Efficiency of Energy Users

Energy users were thus analyzed based on two aspects: (i) the energy usage, i.e., the electricity consumption and contract capacity, and (ii) the scale and management structure of the factory, such as the number of employees and the rank of the energy administrator. Based on these considerations, the contract capacity, electricity usage, employee count, and rank of the energy administrator were selected as independent variables for regression; these variables and their expected impact on the energy user are detailed as follows:

1. The contract capacity is an important metric of a user's electricity usage. In Taiwan, the contract capacity is usually set based on the maximum electricity demand during the peak hours of summer months by the factory and the Taiwan Power Company (Taipower). Therefore, the contract capacity can reflect the electricity demand status of the factory; the greater the electricity demand of the factory, the higher the contract capacity.
2. Electricity usage is another important metric of a user's electricity consumption. Whereas the contract capacity is measured in power, i.e., kilowatts (kW), the electricity usage is measured in kWh; the electricity usage includes the operating hours and thus better represents the actual electricity usage of the factory. Higher factory electricity usage may represent more equipment in the factory or a larger-scale facility with more product output.
3. Employee count is a relatively intuitive metric; larger factories have more employees.
4. As discussed above, the rank of the energy administrator may affect whether the factory can promote larger electricity saving plans. As lower-ranking employees have less budgetary control, the factory is more inclined to promote small-scale projects and equipment maintenance rather than larger-scale energy saving projects. Higher-ranking employees are more likely to promote large-scale energy saving plans and thus achieve the target electricity saving. The ranks of the energy administrators were divided into five categories according to their job titles: (1) other, indicating a job title of no clear level or that cannot be classified; (2) general staff, indicating a commissioner, engineer, administrator, foreman, technician, worker, general affairs, or environmental safety personnel; (3) section manager, indicating a section leader, senior engineer, senior commissioner, team leader, group leader, department leader, or junior manager; (4) factory executive, indicating a factory director, factory sub-director, division chief, manager, or deputy manager; and (5) company executive,

indicating the chairman, chief executive officer, executive director, general manager, deputy general manager, or the director.

4.2. Hypotheses

Based on the studies by Pan and Lee [42] and the experience of energy auditors of Taiwanese energy users, four hypotheses were formulated regarding the impact of each of the above variables on the ability to meet the electricity savings targets:

1. The contract capacity of an energy user is positively associated with their likelihood of achieving the target of 1% electricity saving.
2. The electricity usage of an energy user is positively associated with their likelihood of achieving the target of 1% electricity saving.
3. The employee count of an energy user is positively associated with their likelihood of achieving the target of 1% electricity saving.
4. An energy user is more likely to achieve the target of 1% electricity saving when the role of energy administrator is held by a higher-ranking employee.

4.3. Research Methodology and Data Processing

The energy audit data provided by the energy users in 2018 [3] were processed by first removing any entries containing blank data fields or completed by a person other than the energy administrator to ensure the quality of the data. For the remaining 2392 energy users, binary logistic regression was performed on the status of reaching the 1% electricity saving target. The independent variables included the contract capacity, employee count, electricity usage, and rank of the energy administrator.

As the energy users belong to different industries and industrial characteristics may affect users' energy efficiency, users were also classified by industry. Based on their level of energy consumption, priority was given to the petrochemical, electronics, iron and steel, cement, paper, textile, and food industries; their total energy consumption exceeded 80% of the overall energy consumption of the industrial sector, as shown in Figure 3.

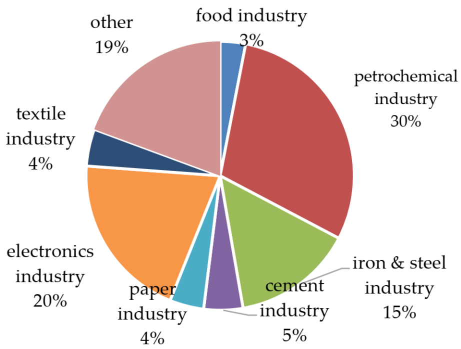

Figure 3. Breakdown of energy consumption in Taiwan's industrial sector by industry [1].

The users were then categorized according to their production patterns and intensity as high-tech (electronics), heavy (petrochemical, iron and steel, and cement), or general (textile, paper, food, and other) industries, representing 578, 798, and 1016 energy users, respectively. Regression analysis was then performed based on these classifications to understand the factors affecting energy users' ability to achieve the targeted 1% electricity saving.

4.4. Logistic Regression

Logistic regression models a relationship between independent variables and a categorical dependent variable. When we want to predict something, the most commonly used statistical tool is regression. If the dependent variable is continuous, linear regression can be used. However, in some cases, the collected data are binary (e.g., yes/no, win/lose, or pass/fail) and the dependent variables have only two categories. The dependent variable is assigned a probability between 0 and 1. Therefore, we need to use logistic regression to deal with binary type cases.

In this study, logistic regression was performed on the status of reaching the 1% electricity saving target for energy users. The mathematical formulation of the logistic regression method is shown as follows:

$$\log\left(\frac{\pi(X)}{1-\pi(X)}\right) = \alpha + \beta x, \tag{2}$$

$$\frac{\pi(X)}{1-\pi(X)} = \exp(\alpha + \beta x), \tag{3}$$

$$\pi(X) = \frac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)}, \tag{4}$$

and the relationships between $\pi(X)$ and X in the mathematical formula are usually nonlinear. Nonlinear relationships between $\pi(X)$ and X are usually monotonic. π is the probability that an observation is in a specified category of the binary dependent variable. A fixed change may have an impact when $\pi(X)$ is near 1 or 0 than when $\pi(X)$ is near the middle of its range. The parameter β in the model determines the rate of increase or decrease of the curve function $\pi(X)$. When $\beta > 0$, $\pi(X)$ increases as x increases. On the other hand, when $\beta < 0$, $\pi(X)$ decreases as x decreases.

5. Results and Discussion

A binary logistic regression was first conducted for the 2392 energy users studied to understand the factors that affect energy users' ability to achieve the energy savings target. Next, the differences between the users classified in the high-tech, heavy, and general industries were compared via regression analysis.

5.1. Logistic Regression Results

Of the four independent variables being studied (i.e., contract capacity, electricity usage, employee count, and energy administrator level), the rank of the energy administrator, needed to test hypothesis 4, is a categorical variable.

The results of the regression, shown in Table 1, demonstrated that the contract capacity did not significantly impact (*p*-value) the users' ability to meet the targeted 1% electricity saving. Thus, hypothesis 1 does not hold; contract capacity does not have a significant impact on a user's probability of meeting the targeted electricity saving.

The electricity usage was demonstrated to have a significant effect on users' ability to achieve the electricity saving target, but the electricity usage coefficient of electricity usage is negative. The coefficient of electricity usage in the exponential is 0.999, indicating that higher electricity usage does not positively correlate with a user's likelihood of meeting the electricity savings target and that hypothesis 2 does not hold.

The number of employees was determined to be highly significant (*p*-value) and the regression coefficient was positive. Thus, hypothesis 3 holds; a greater number of employees corresponds to an increased likelihood of users achieving the 1% electricity saving target.

Table 1. Overall energy users' logistic regression results.

	Regression Statistics Estimate	Std. Error	z Value	Pr (>|z|)
Intercept	9.145×10^{-1}	1.530×10^{-1}	5.977	2.28e−09 ***
Contract capacity	6.599×10^{-7}	5.824×10^{-6}	0.113	0.909797
Employee count	5.282×10^{-4}	1.400×10^{-4}	3.772	0.000162 ***
Electricity usage	-9.517×10^{-7}	5.110×10^{-7}	−1.863	0.062516
Energy administrator class 2	3.357×10^{-1}	1.724×10^{-1}	1.948	0.051415
Energy administrator class 3	6.050×10^{-1}	1.836×10^{-1}	3.295	0.000983 ***
Energy administrator class 4	6.776×10^{-1}	2.101×10^{-1}	3.226	0.001257 **
Energy administrator class 5	3.809×10^{-1}	3.276×10^{-1}	1.163	0.244990

Significance: "***", 0.001; "**", 0.01.

5.2. Impact of Energy Administrator Level

Energy administrators classified as other (category 1, as detailed in Section 4.1) were used as a reference group. According to the regression results, the rank of the energy administrator was significant for ranks 2–4; higher-ranking energy administrators, except for company executives, were correlated with an increased likelihood of achieving the electricity saving target, as shown in Table 1. Taking the exponential for the regression coefficient, the coefficient of factory executive was 1.969, the coefficient of section manager was 1.831, and the coefficient of general staff was 1.398.

To understand why this correlation did not hold for the highest-ranking administrators (i.e., rank 5, company executives), the other characteristics of the energy users were compared, as shown in Table 2. Energy users with administrators of rank 5 (i.e., company executives) tended to be small-scale factories with less than 100 employees and had lower contract capacities and electricity usage than those with mid-ranking energy administrators.

For these smaller-scale factories, a high-ranking energy administrator may have other duties unrelated to their energy administrator position, such as product quality, production volume, environmental protection, and labor safety. Therefore, if a company executive is appointed as energy administrator, it is more likely that he or she will split his or her time and resources, thus reducing the likelihood of achieving ambitious energy saving goals when compared with mid-ranking counterparts.

Table 2. Factory characteristics broken down by the rank of the energy administrator [3].

Rank	Average Number of Employees	Average Contract Capacity (kW)	Average Electricity Usage (kWh)
5: Company executive	87	1957	9,651,915
4: Factory executive	486	10,895	69,626,409
3: Section manager	399	7031	60,847,099
2: General staff	480	8454	87,178,114
1: Other	203	2076	18,718,240

Furthermore, company executives are responsible for managing the entire company, not just the factory; factory executives are often closer to the production status and energy usage of the factory and thus may be better suited to promote energy saving plans. The regression results demonstrate this as well; energy users with factory executives appointed as energy administrators had the greatest likelihood of meeting the target energy performance.

Overall, of the mid-ranking energy administrators (i.e., rank 2–4), those classified as factory executives and section managers had a more pronounced impact than did the general staff. These higher-ranking management officials likely have greater budgetary control to promote larger energy saving plans and can communicate more effectively across departments to facilitate their smooth completion.

Thus, hypothesis 4 holds partly true. Within the management structure of the factory (i.e., excluding rank 5, company executives), energy users with higher-ranking energy administrators are more likely to achieve the targeted 1% electricity saving.

5.3. Group Classification Regression Results

To determine the impact of industry type on the likelihood of meeting the targeted 1% electricity saving, binary logistic regression was then performed for each of the three industry types (i.e., the high-tech, heavy, and general industries); the basic information of energy users for each industry is summarized in Table 3. This breakdown demonstrates that high-tech factories had approximately 3–4 times more employees than heavy or general industries, although the different industries had similar average contract capacities and average electricity usages.

Table 3. Overview of energy users belonging to each industry [3].

Industry Type	Average Number of Employees	Average Contract Capacity (kW)	Average Electricity Usage (kWh)
High-tech	835	7794	63,787,551
Heavy	231	7589	60,112,456
General	221	2450	18,750,996

The results of the logistic regression for the users classified as high-tech industry, shown in Table 4, demonstrated no significant difference between energy users in the high-tech industry and all industries combined. The number of employees and the rank of the energy administrator were also the main factors affecting the users' energy efficiency. However, the rank of the energy administrator was not statistically significant by *p*-value as in the overall energy user regression analysis.

High-tech industrial facilities commonly have clear management structures and employees with a clear understanding of their responsibilities. Compared with their heavy and general industry counterparts, high-tech industrial facilities have shorter product life-cycles and faster changes in the industry and thus have more work content in the form of project plans. Employees in the high-tech industry are thus more familiar with the promotion of energy saving plans in the form of projects and require less time to adapt. Further, high-tech industrial facilities tended to have a greater number of employees and a relatively higher degree of organizational flexibility, making the appropriate authorization and organizational changes more effective. Combined, these aspects may reduce the impact of the rank of the energy administrator on the likelihood of meeting the energy saving target.

Table 4. Logistic regression results for the high-tech industry.

	Regression Statistics Estimate	Std. Error	z Value	Pr (>|z|)
Intercept	6.661×10^{-1}	5.015×10^{-1}	1.328	0.18406
Contract capacity	-1.012×10^{-4}	7.091×10^{-5}	-1.428	0.15336
Employee count	6.320×10^{-4}	2.239×10^{-4}	2.823	0.00476 **
Electricity usage	1.106×10^{-8}	8.884×10^{-9}	1.245	0.21304
Energy administrator class 2	3.948×10^{-1}	5.157×10^{-1}	0.766	0.44395
Energy administrator class 3	8.907×10^{-1}	5.371×10^{-1}	1.658	0.09729
Energy administrator class 4	9.462×10^{-1}	5.630×10^{-1}	1.681	0.09284
Energy administrator class 5	8.640×10^{-1}	1.203	0.718	0.47261

Significance: "**", 0.01.

The results of logistic regression for the users classified as heavy industry, summarized in Table 5, were similar to those of the overall energy users. The number of employees and the rank of the energy administrator were the main factors affecting the users' energy efficiency, both of which had a positive correlation with the likelihood of meeting the targeted 1% electricity saving.

In heavy industry, the factory system department (or utility department) is mainly responsible for energy management or energy-efficiency-related matters. These departments provide the electricity, compressed air, and steam required to maintain smooth production, allowing the factory to produce high-quality products and increase production. The factory system department must stably supply the energy needed for production and maintain a good production environment. However, promoting a plan to save electricity usage may cause instabilities in the production line owing to replaced equipment or an adjusted production environment. Such instabilities lead to a decrease in product quality or in production volume and present liability risks, which would not be taken by energy administrators. This is a common problem faced by energy users in the promotion of an energy saving plan.

An examination of the air compressor system can be used to illustrate this inherent tradeoff between the factory system department and the production department. Although the pressure of the compressed air is required to be more than 4 kg/cm^2 for the pneumatic valve of common manufacturing equipment, any drop below 4 kg/cm^2 could lead to unstable production. As a result, the factory system department generally keeps the outlet pressure above 7 kg/cm^2 to reduce its liability risks; however, this unnecessarily increased pressure results in wasted electricity. If increasing the rank of the energy administrator enables cross-departmental coordination, the problem of excessive pressure can be solved.

Even if a piece of equipment, such as an air compressor, pump, chiller, or boiler, is under the jurisdiction of the factory system department, it can only be replaced based on the schedule set by the production department. To replace the air compressor, for example, the factory system department must coordinate with the production department, which may not be able to tolerate the stopping of the air compressor. Therefore, even if the factory system department knows that equipment should be updated to improve the electrical efficiency of the facility, promoting energy savings can be difficult due to production responsibilities taking priority.

Selecting higher-ranking energy administrators can mitigate these problems involving inter- and cross-departmental communication, as higher-ranking employees are likely to have experience coordinating among different departments. Factory managers acting as the energy administrator are thus most likely to initiate cross-departmental communication and assist in the smooth implementation of an energy savings plan.

Table 5. Logistic regression results for the heavy industry.

	Regression Statistics Estimate	Std. Error	z Value	Pr (>|z|)
Intercept	7.033×10^{-1}	2.555×10^{-1}	2.752	0.00591 **
Contract capacity	5.313×10^{-7}	8.638×10^{-6}	0.062	0.95095
Employee count	7.797×10^{-4}	4.129×10^{-4}	1.888	0.05899
Electricity usage	-7.874×10^{-10}	1.039×10^{-9}	−0.758	0.44871
Energy administrator class 2	4.678×10^{-1}	2.889×10^{-1}	1.619	0.10534
Energy administrator class 3	6.234×10^{-1}	3.017×10^{-1}	2.066	0.03883 *
Energy administrator class 4	6.566×10^{-1}	3.435×10^{-1}	1.911	0.05598
Energy administrator class 5	4.726×10^{-1}	4.982×10^{-1}	0.949	0.34282

Significance: "**", 0.01; "*", 0.05.

As in the heavy industry, the energy management and energy efficiency of energy users in the general industry are dominated by the factory system department, resulting in similar problems involving cross-departmental communication. Unlike the heavy and high-tech industries, the number of employees in general industry facilities was positively correlated with a user's likelihood of meeting the energy savings target, as demonstrated by the results of logistic regression summarized in Table 6. However, this positive correlation was not statistically significant.

The difference in the influence of the number of employees may be explained by differences in production environment between energy users classified as heavy and general industry. Energy users classified as heavy industry use more large-scale equipment, which is often equipped with a control panel or separate operating room. The on-site production staff only observe the changes in the equipment monitoring data and perform appropriate operations, thus requiring less manpower. On the contrary, energy users classified as general industry have more equipment and production lines that rely more heavily on on-site manpower. As the production manpower required by the general industry is relatively high, this reduces the manpower of other departments, including the factory system department. Thus, general industry facilities have limited manpower for the implementation of plans to save electricity consumption, even if the average number of employees is similar to that seen in heavy industry. The above phenomenon may reduce the impact of the number of employees on the likelihood of meeting the energy saving target.

Table 6. Logistic regression results for the general industry.

	Regression Statistics Estimate	Std. Error	z Value	Pr (>∣z∣)
Intercept	1.147	2.157×10^{-1}	5.320	1.04×10^{-7} ***
Contract capacity	-8.168×10^{-6}	2.940×10^{-5}	−0.278	0.7812
Employee count	3.054×10^{-4}	3.157×10^{-4}	0.968	0.3333
Electricity usage	-2.288×10^{-9}	1.121×10^{-9}	−2.041	0.0412 *
Energy administrator class 2	3.139×10^{-1}	2.449×10^{-1}	1.282	0.1999
Energy administrator class 3	5.931×10^{-1}	2.676×10^{-1}	2.216	0.0267 *
Energy administrator class 4	6.991×10^{-1}	3.246×10^{-1}	2.153	0.0313 *
Energy administrator class 5	2.482×10^{-1}	4.719×10^{-1}	0.526	0.5990

Significance: "***", 0.001; "*", 0.05.

Overall, across all industry types, the main factors found to affect energy users' ability to achieve the targeted 1% electricity saving are the employee count and rank of the energy administrator, as summarized in Table 7.

Table 7. Analysis of regression results and hypothesis confirmation.

	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4
All energy users	X	X	○	○
High-tech industry	X	X	○	○
Heavy industry	X	X	○	○
General industry	X	X	X	○

Note: X = Reject, ○ = Accept.

6. Conclusions

By performing comprehensive logistic regression and hypothesis verification of the impact of four independent variables on the likelihood of an energy user meeting the targeted 1% electricity saving, energy-related factors, such as the contract capacity or electricity usage, were demonstrated to have no significant correlation with an energy user's ability to meet the target. In contrast, management-related factors such as the number of employees and the rank of the energy administrator were significantly correlated with an energy user's likelihood of meeting the targeted electricity saving of 1%.

As it is difficult to increase the number of employees rapidly, the effort to improve energy efficiency should thus focus on increasing the rank of the energy administrator. Increasing the rank of the energy administrators within the management structure of the factory (i.e., excluding company executives) demonstrated a clear correlation with an increased likelihood of users meeting the electrical saving targets, likely due to their increased budgetary control and cross-departmental communication abilities that allow them to promote bolder and broader energy saving plans. Energy users should thus select a factory executive or section manager when choosing their energy administrator. Future efforts should further explore the relationship between the rank of the energy administrator and the proposed energy saving plans.

To achieve the 1% electricity saving target, some policies may be considered, such as amending the law to strengthen the punishment for users who fail to meet the target or granting tax incentives to energy users with outstanding performance in electricity saving. However, the aforementioned policies may require energy law revision or frequent and repeated interdepartmental consultations and confirmations between different government agencies before they can be launched. In this study, we primarily focused on the energy administrator factor. Since it is solely under the authority of the Bureau of Energy, the above-mentioned challenges could be avoided.

Energy efficiency improvement can be challenging, with diminishing returns. According to the results of this research, the adjustment of the energy management structure can stimulate the potential of energy saving for energy users. We believe that clearly defining the rank of the energy administrator should be one of the government's future policies. The government can consider promoting the concept that the rank of the energy administrator is important for energy efficiency improvement and encouraging energy users to choose suitable employees to serve as energy administrators. Furthermore, the government may consider combining corporate social responsibility (CSR) with the issue of the energy administrator and including the concept of the energy administrator in environmental, social, and governance (ESG) enterprise.

Finally, based on the findings of our research, we put forward a point of view that energy users' efforts to improve energy efficiency and achieve electricity saving targets can be facilitated not only by the introduction of new technologies or new equipment to improve energy efficiency but also through adjustments to the management structure of energy administration.

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