Mandatory energy conservation target: a case study of 1 % electricity saving in Taiwan's industrial sector

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Abstract

Because Taiwan will be at a risk of power shortage in the coming years, the promotion of electricity conservation is critical. In 2014, the industrial sector was responsible for approximately 54 % of the country's total electricity consumption. Therefore, the electricity conservation by the industrial sector is particularly important. To improve the energy efficiency of industries in Taiwan, the government has mandated a target of 1 % electricity saving for all large energy users (LEUs) with contract capacities higher than 800 kW. Approximately 3,200 factories qualify as LEUs, and they account for 89 % of the industrial sector's electricity consumption. Every LEU must implement electricity conservation measures, and the annual average electricity saving from 2015 to 2019 must exceed 1 % of the annual average total electricity consumption. Moreover, electricity saving from one energy efficiency measure will be counted only in one year.

According to a survey carried out in this study, in 2015 about 61 % of industrial LEUs are expect to achieve the target of 1 % electricity saving in next five years. Furthermore, questionnaire results show a positive correlation between the ratio of LEUs achieving mandatory target and the number of employees at industrial LEUs. LEUs with more employees can allocate more resources to implement energy efficiency projects. Forty-three percent of LEUs who will achieve the mandatory target will improve the energy efficiency of their manufacturing processes as their primary electricity conservation measure. Furthermore, a major barrier for 46 % of LEUs that will fail to satisfy the mandatory target is that the proportion of electricity consumption in their essential manufacturing facilities is high, and these facilities cannot be improved in a short term. With respect to assistance to achieve the target of 1 % electricity saving, more than 44 % of LEUs expect the government to subsidize high-efficiency facilities, and 19 % of LEUs require energy conservation diagnosis and consultation.

Introduction

Because of Taiwan's economic growth, the annual growth rate of electricity demand in Taiwan was approximately 1.8 % during 2005–2014. According to a draft of the Energy Development Policy Report announced by the Bureau of Energy (BOE) in Taiwan, electricity demand will increase continually, and the annual average growth rate of electricity demand from 2015 to 2035 will be 1.5 % (BOE, 2015). However, environmental awareness in Taiwan is increasing, and local residents oppose to building new electric power plants. Taiwan is an island without links to the grids of other countries. As economy grows and electricity demand increases, Taiwan will be at a risk of power shortage. Since the supply side is difficult to improve, raising energy efficiency on the demand side must play an important role.

With respect to electricity consumption by various sectors in 2014, industrial, commercial, and residential sectors accounted for 53 %, 19 %, and 18 %, respectively. Because electricity consumption in the industrial sector is significantly higher than those in other sectors, electricity conservation in the industrial sector is essential. During 2007–2014, the annual improvement rate of electricity intensity (electricity consumption/GDP) in the industrial sector was 3.0 %, which is better than the national

rate (1.9 %). To motivate further improvements in energy efficiency, the BOE established a mandatory target for large energy users (LEUs) based on the current mandatory energy audit scheme. Under this mandatory target, the LEU's annual average of electricity saving from 2015 to 2019 must exceed 1 % of the annual average of total electricity consumption.

However, not all LEUs will be able to achieve this mandatory target. Therefore, an investigation of the LEUs' attitudes, barriers, or need for assistance to achieve the 1 % electricity savings would be useful for the BOE to support these LEUs to improve their electricity efficiencies. In this study, we identify the LEUs' viewpoints regarding the 1 % electricity saving target by their responses to a questionnaire survey. The remainder of this paper is organized as follows. In the next section the energy audit scheme is explained first, because the administrative procedure for the 1 % electricity saving is based on this scheme. Next, the procedure of mandatory target is described. Finally, the LEUs' attitudes, barriers, or assistance required with respect to the 1 % electricity saving target for different sub-sectors, are presented based on the results of the questionnaires.

Mandatory Energy Audit in Taiwan

The energy audit is the center of the industrial energy efficiency program as it can provide detailed information regarding energy use as well as show the potential for saving (eceee, 2014). In Taiwan, the mandatory energy audit was initiated in 1980s. According to the Energy Management Law, each LEU must establish its own energy audit system in conjunction with its own energy conservation target and implementing action plan, which shall be carried out upon approval by the BOE. Recognition of LEU distinction is based on the LEU's energy consumption. The definition and duties of LEUs are listed in Table 1.

The criteria of LEU consider the energy consumption of different energy forms, such as natural gas, coal, and steam. Because the electricity contract capacities of all the industrial LEUs are greater than 800 kW, the major LEU criterion is the electricity contract capacity. In 2015, the number of industrial LEUs was about 3,200. They consumed about 89 % of the total electricity demand of the entire industrial sector.

The mechanism of the mandatory energy audit is shown in Figure 1. Each year, the BOE produces a list of all the LEUs, based on energy consumption data, and holds training courses to illustrate what information should be included in the mandatory energy audit report. These information requirements are roughly the same each year, but the BOE may occasionally ask LEUs to report additional information for specific management purposes, such as the 1 % electricity saving. In general, the annual energy audit reports submitted by LEUs must include the information listed below:

1. Basic information: site address; number of employees; amount of authorized capital; and framework of in-house energy management organization.
2. Status of energy consumption: monthly energy consumption of coal, oil, natural gas, and electricity; electricity purchased; energy consumption for cogeneration; specification (such as, water content) and heat value of fuel.
3. Energy efficiency indicators for products and facilities: specific energy consumption for products; number and design efficiency of facilities.
4. Graphs of energy balance: flow chart of production; graph of electricity balance; and graph of thermal balance.
5. Energy conservation report: budget, period, and savings related to energy conservation measures for previous year's achievement and this year's plan.

LEUs must submit an energy audit report detailing the previous year's energy consumption either on paper, electronic file, or a web-based reporting platform. To improve the quality of the LEUs' energy audits, the BOE commissioned the Industrial Technology Research Institute (ITRI) to evaluate the accuracy of the industrial LEUs' energy audit reports and to develop a database system to store industrial LEUs' historical energy audit information. With the assistance of the energy audit database system, the completeness of each LEU's energy audit can be routinely reviewed and analyzed. For example, the database system can incorporate external data, such as electricity bills from utilities, to check the accuracy of energy audit reports. Moreover, if the pattern of an LEU's energy consumption one year differs markedly with those of past years, the database system would inform the LEU or ITRI staff to recheck the data.

In addition to checking document accuracy, the ITRI also samples about 400 factories from industrial LEUs each year to verify the energy audit reports on-site. If the LEU's energy au-

Table 1. Definition and duties of large energy user.

Type	Energy Form	Criteria of LEU	Mandatory Obligation
I	Electricity	Contract capacity >800 kW	1. By the end of January each year, LEUs must report to the BOE the previous year's energy consumption data in conjunction with the current year's energy auditing scheme, energy conservation target, and action plan. 2. LEUs must establish an energy management officer. 3. The installation of new energy facilities or expansion of existing facilities must be approved by the BOE.
	Fuel oil	>6,000 kl/y	
	Natural gas	>10 million m^3/y	
	Coal	>6,000 ton/y	
II	Steam	>100 ton/h	LEU has to set up cogeneration (CHP) system.
III	Centralized air conditioning system	Not for production use and refrigeration capacity over 100 hp	Provide space and wire connection boxes for necessary meters installed by electricity utilities.

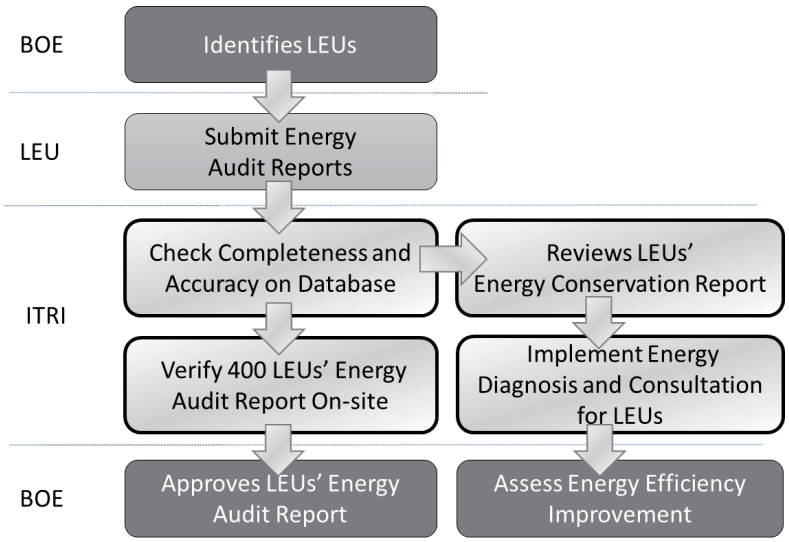

Figure 1. Mechanism of Taiwan mandatory energy audit.

Table 2. Comparison between Taiwan and EU energy audit scheme.

	Taiwan Energy Management Law	**EU Energy Efficiency Directive Article 8**
Designate Energy User	Location-level (such as factory)	Company-Level
Distinction of Energy Audit	Based on Energy Consumption Criteria	Based on Financial and Employment Criteria
Frequency for Energy Audit	1 year	4 years
Requirement of Energy Conservation Target	Voluntary for Energy Demand; Mandatory for Electricity Demand	Voluntary (Energy Performance Indicators)
Link to ISO 50001	No.	Yes.
Energy Auditor	Energy Management Operator in-house.	Qualified and/or Accredited Expert.

dit is correct, the BOE approves the energy audit report. If the LEU's energy audit is unclear or incorrect, the ITRI instructs the LEU to check and revise its report, as Figure 1 shows. Should any LEU fail to reply with an explanation or a revision of their energy audit report, it is fined approximately €800 to €4,000. Furthermore, based on the energy conservation report submitted by an LEU, the ITRI can analyze the LEU's improving progress in energy efficiency and provide energy diagnosis and consultation to LEUs who have the potential to improve their energy efficiency.

Following Article 8 of the Energy Efficiency Directive, the European Union (EU) is actively increasing the number of its energy audits. The differences in the energy audit schemes of Taiwan and the EU are shown in Table 2. In Taiwan's Energy Management Law, designated energy users, such as factories, are defined at the location-level, whereas they are defined by the EU Energy Efficiency Directive at the company-level, such as an enterprise. Recognition of company distinction for mandatory audits in the EU is based on their financial and employment criteria (Eichhammer and Rohde, 2016). However, some companies have a high turnover, but not much energy demand, such as financial institutions. Therefore, Taiwan's criteria are based on energy consumption. The frequencies for implementing energy audits by designated energy users in Taiwan and the EU are 1 year and 4 years, respectively. EU mandatory energy audits are linked to the ISO 50001 and established the standards for auditor. Currently, Taiwan's mandatory energy audit scheme and the ISO 50001 are two independent systems and no link.

Mandatory Target of 1 % Electricity Saving

According to the requirement to carry out a mandatory energy audit, LEUs must set a voluntary energy saving goal in their energy conservation reports. Figure 2 indicates that the average electricity saving rates for all industrial LEUs were close to 1 % in the past 6 years. And the average electricity saving rates for LEUs who saved electricity more than 1 % were over 3 %. However, 60 % to 70 % of LEUs saved less than 1 %, and the av-

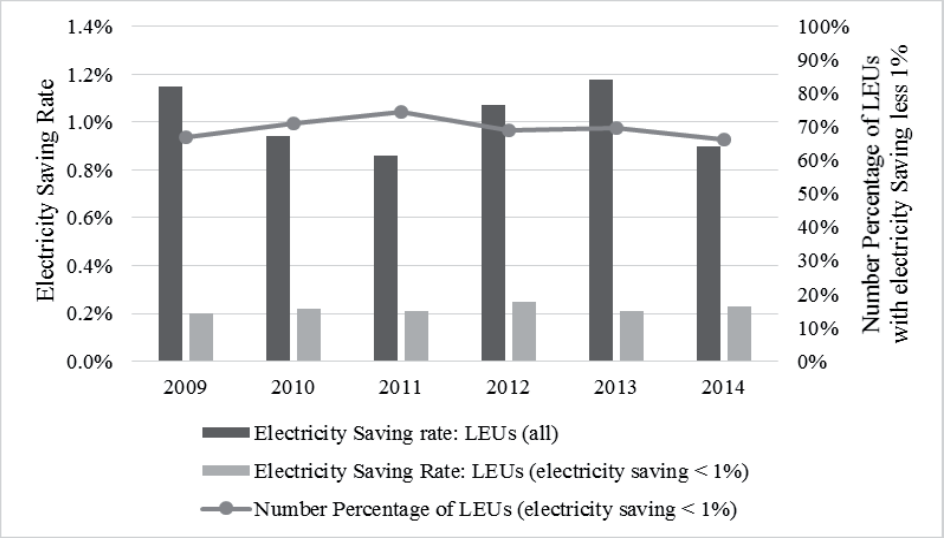

Figure 2. Electricity saving rate for industrial LEUs.

erage saving rate for LEUs that did not achieve a savings of 1 % was only about 0.2 %. Therefore, to ensure the improvement of electricity efficiency in all LEUs, establishing a mandatory target for electricity conservation was essential.

To avoid power shortage problems in coming years, the BOE introduced the "Regulation of Energy Conservation Target and Action Plan for Large Energy Users" in 2014. According to this regulation, the annual average electricity saving rate for LEUs must be higher than 1 % from 2015 to 2019. Because electricity consumption in the industrial or commercial sectors is related to economic growth, the mandatory target, rather than restricting the amount of electricity consumption, requires an accounting of the savings achieved from electricity conservation measures. The electricity saving rate for LEUs is calculated as the electricity saved from measures implemented divided by the electricity consumption, as expressed below:

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

where R_n is the electricity saving rate in year n; S_i is the electricity saving from specific measures in year i; and C_i is the electricity consumption in year i. Since the regulation of mandatory electricity saving was initiated in 2015 and will end in 2019, the year i in this equation begins with 2015. Electricity saving (S_i) is the sum of the electricity saved from different measures in year i. To avoiding double counting, the time frame for electricity saving from measures implemented is up to 12 months. For example, if a factory replaces an IE1 motor with an IE3 motor in September 2015, the electricity saving is counted from October 2015 to September 2016. Even if the IE3 continues to work beyond October 2016, the electricity saved from replacing the IE1 motor is counted only for 12 months.

In the equation of electricity saving rate, the numerator is electricity saving, and the denominator is energy consumption plus electricity saving. If an LEU's annual electricity saving rate is less than 1 %, the LEU must provide an explanation. The annual average rate of electricity saving for an LEU must be more than 1 % in 2019, or the LEU will be penalized by the BOE.

In the energy audit scheme, as shown in Figure 1, LEUs must submit an energy conservation report to BOE, and electricity conservation report is one part of energy conservation report. To ensure each LEU's progress in achieving 1 % electricity saving, the BOE has commissioned the ITRI to review the appropriateness of the electricity conservation measures listed in each LEU's electricity conservation report. As shown in Figure 3, as the BOE receives an electricity conservation report from an LEU, it will first check the LEU's claim of having achieved the 1 % electricity saving. Once verified, the ITRI will then review the LEU report in detail to ensure that the achieved electricity savings are derived from appropriate electricity conservation measures. If the implemented measures and calculations of electricity saving are reasonable, the BOE approves the LEU's electricity saving report.

If an LEU's electricity saving rate is less than 1 %, the LEU must explain the reasons for the failure and provide evidence documents. When the ITRI receives the LEU's reply, external experts are invited to check that the LEU's reasons are acceptable. Currently, there are six categories of appropriate reasons.

1. New production lines have increased electricity consumption.
2. Researching for the manufacturing process upgrade has increased electricity consumption.
3. In response to an emergency, the energy user has increased electricity consumption. For example, to reduce the impact of drought, a water supply plant (LEU) may have pumped more water to water-shortage areas, thus raising its electricity consumption.
4. Because many electricity conservation measures were implemented in past years, the LEU is unable to achieve the mandatory target in the previous year.
5. Manufacturing facilities that consume the most electricity cannot be improved in the short term. Even though other electricity conservation measures were implemented, the electricity saving rate remained less than 1 %.

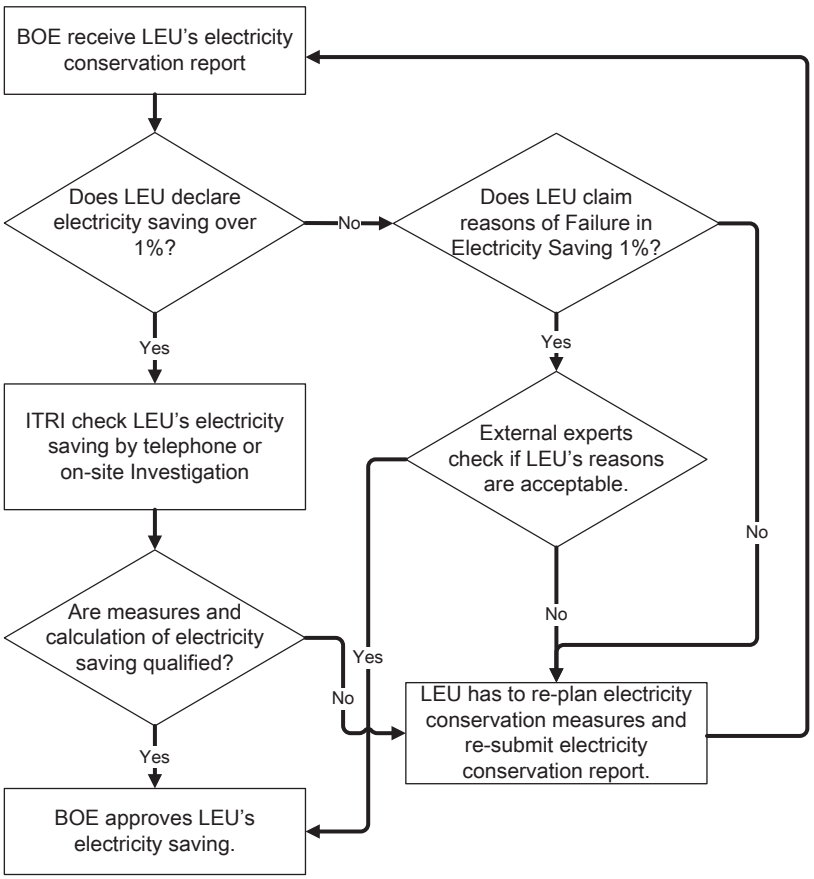

Figure 3. Flow chart for reviewing electricity conservation reports.

6. Other reason. For example, the factory's energy efficiency is the top runner in its industry, or the factory will be closed this year.

If the external experts agree that the LEU's reply is reasonable regarding its failure to achieve the mandatory target in this year, the LEU must still make up for this year's shortfall in electricity savings in the coming year and meet the target of average annual electricity saving 1 % from 2015 to 2019 in 2019. If the LEU's reply is not deemed to be reasonable, the LEU must re-develop its electricity conservation measures and re-submit its electricity conservation report.

Furthermore, the purpose of setting LEU's mandatory target is to ease the power shortage problem in Taiwan. Therefore, if electricity generated from an LEU's renewable power facility, such as solar panels or waste heat recovery power generator, is consumed by the LEU itself and not sold to another company or utility, electricity generated from those clean energy sources is regarded as electricity savings. Moreover, since the mandatory target focuses on electricity, an LEU's energy saving from coal, oil, or natural gas is not regarded as electricity saving.

Expected Achievement and Barriers to Attaining the Mandatory Target

To gain better understanding of the LEU's attitudes toward mandatory targets, this study delivered questionnaires to 342 LEUs sampled randomly from 3,200 industrial LEUs in the industrial sector to elucidate the expected achievement, action plans, and barriers to saving 1 % electricity consumption. This questionnaire covers four major topics, the results of which are presented in Figure 4 to 7, respectively.

1. Expected achievement: Will your factory be able to achieve the mandatory target of 1 % electricity savings between 2015 and 2019? (Figure 4)
2. Action plan: In seeking to achieve the mandatory target, which system do you believe would have the greatest effect in improving energy efficiency? (Figure 5)
3. Barriers: What do you believe is the primary barrier to your factory achieving the mandatory target? (Figure 6)
4. Assistance: What assistance would your factory require to meet the mandatory 1 % target? (Figure 7)

The questionnaire results in Figure 4 indicate that approximately 61 % of the LEUs expect to achieve the mandatory target. The fact that 39 % of the LEUs are pessimistic about these forecasts is not particularly discouraging; however, due to the fact that this represents a considerable decrease from the 60~70 % for years ago, as shown in Figure 2. This is an indication that mandatory targets may have had an effect in exerting pressure on LEUs to improve electricity efficiency. Figure 4 also shows that the relationship between authorized capital and the achievement of electricity saving targets is not significant. The authorized capital in this questionnaire is the funding that shareholders invested as company established, and it indicates the financial scale of LEUs. Nonetheless, the relationship between

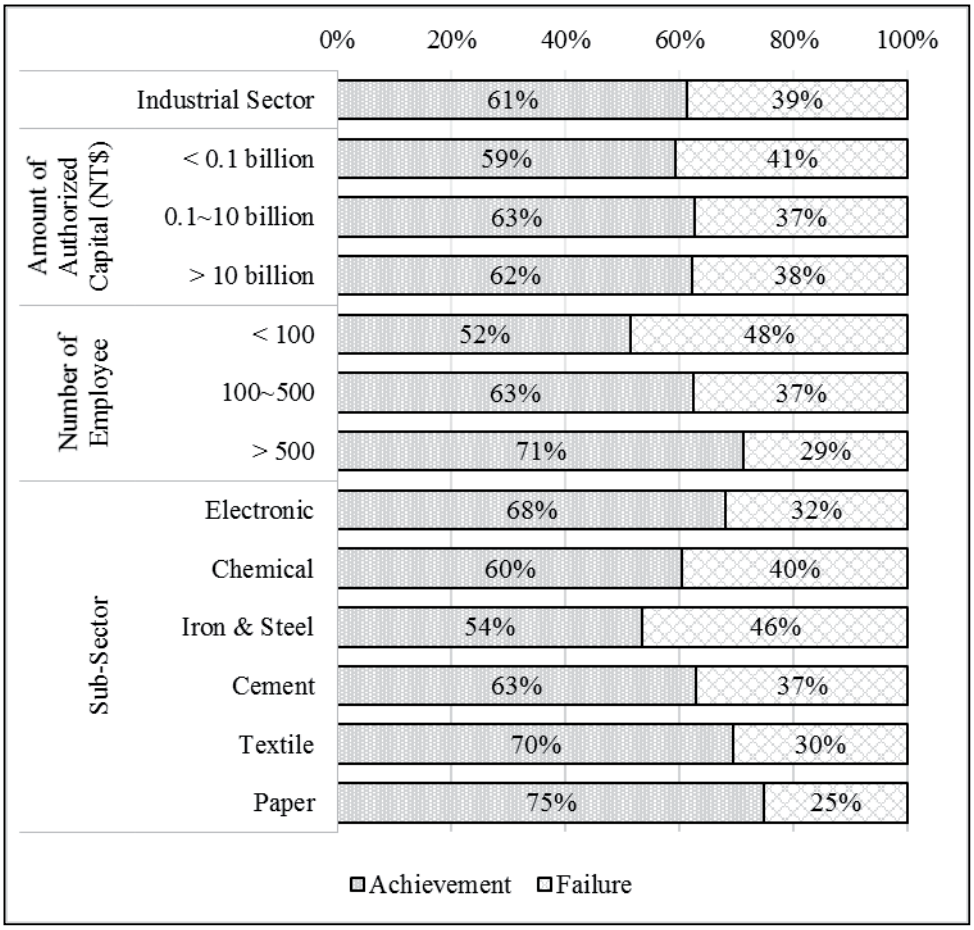

Figure 4. LEUs' expectation of achievement of mandatory targets.

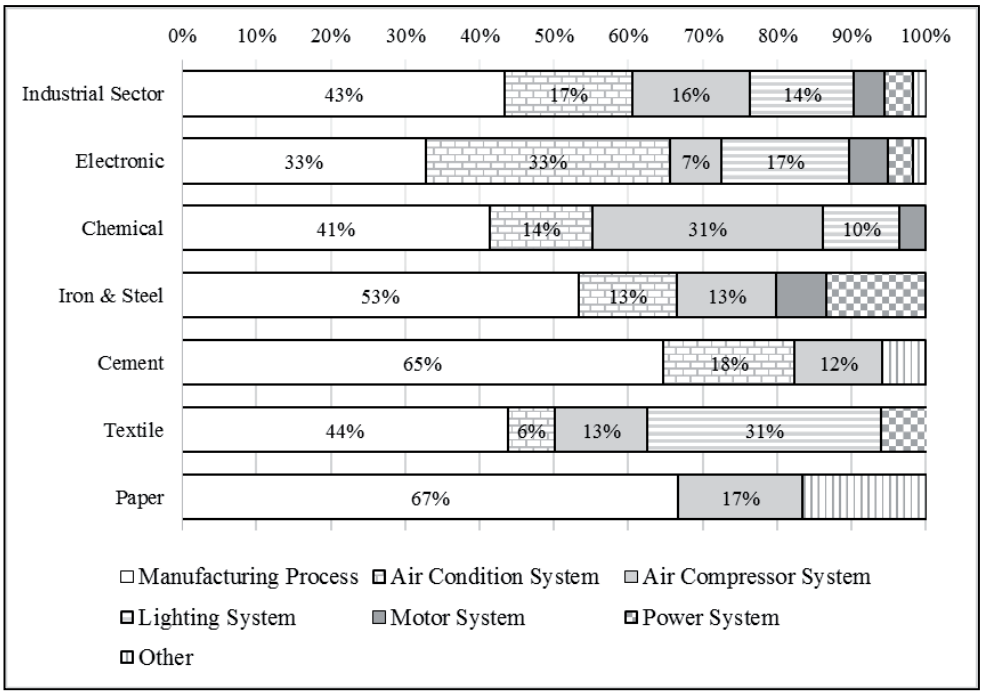

Figure 5. Action adopted by LEUs to achieve mandatory targets.

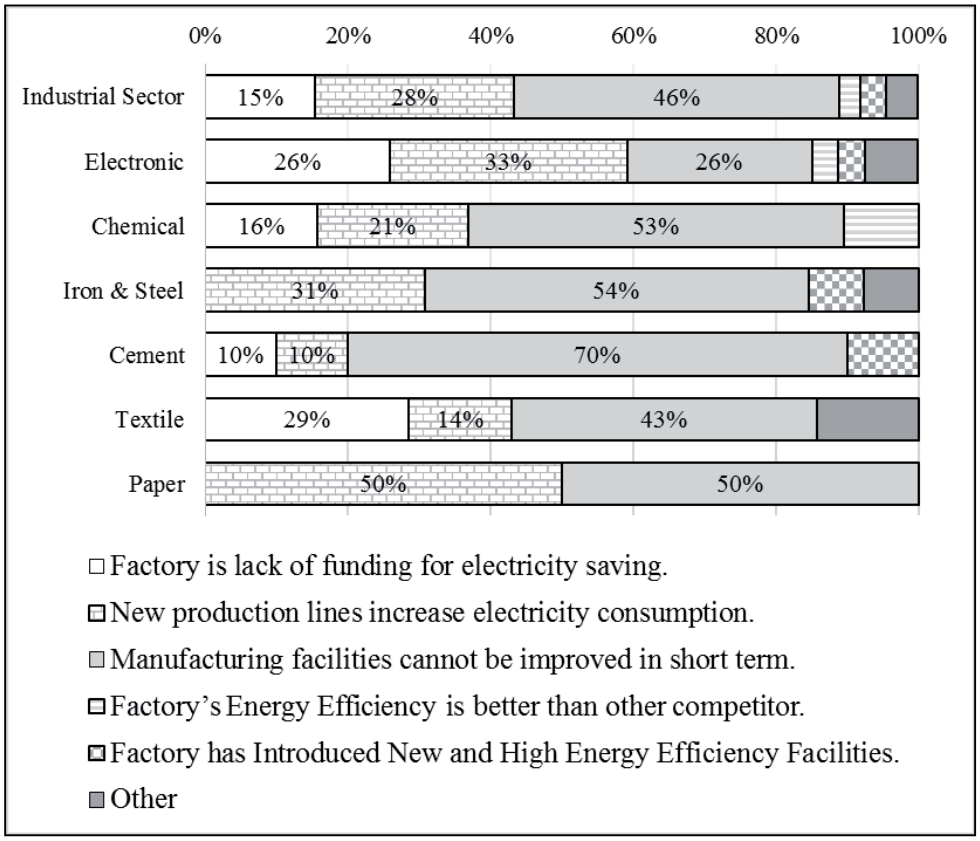

Figure 6. Barriers to LEUs achieving mandatory targets.

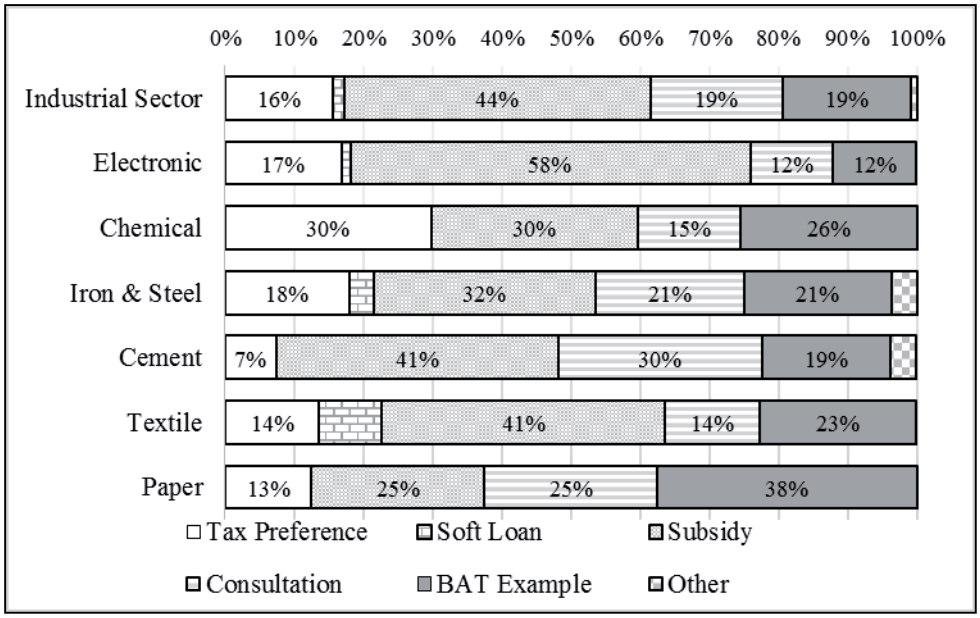

Figure 7. Assistance LEUs need for achieving mandatory targets.

the number of employees and the achievement of electricity saving targets is statistically significant. A higher number of employees was also shown to increase the likelihood of achieving the target. The amount of authorized capital includes fixed capital, which the LEU is unable to invest in electricity conservation. In contrast, larger number of employees means that the LEU has more human resources to be allocated to improving efficiency. This may explain the positive correlation between the number of employees and the likelihood of achieving electricity saving targets.

In Taiwan, the six major energy consuming industries are electronic, chemical, iron and steel, cement, textile, and paper, which account for approximately 76 % of the total electricity consumption of the industrial sector. Differences of six major energy consuming industries in their manufacturing processes and product characteristics lead to differences in

expected achievement, action plans, barriers, and essential assistance. This study therefore examined the questionnaire results from the perspective of each of the major industrial sub-sector.

The electronic industry accounts for 44.9 % of the industrial GDP of Taiwan; however, it also accounts for 32.5 % of the industrial consumption of electricity. As shown in Figure 4, approximately 68 % of the LEUs expect to achieve the mandatory target within the next 5 years. According to the Energy Audit Database for the electronic industry, manufacturing processes account for 44 % of the total electricity consumption, and air conditioning systems that are used to maintain a constant temperature and humidity in clean rooms takes up 26 %. Clearly, these are areas on which electricity conservation efforts will be improved first (Figure 5). The new products of electronic industry have shorter lifespan and are more complicate than old ones; therefore, the implementation of new manufacturing processes for new products does not necessarily reduce electricity consumption. As an alternative, electronic LEUs could seek to modify manufacturing facilities, such as the recovery of waste cool in chiller or improving the insulation around vacuum furnaces. Since chiller and fan systems consume most of the electricity in air conditioning systems, the BOE initiated energy efficiency operation standards for chillers and fans in 2015. Between 2007 and 2014, the electronic industry accounted for 9.7 % of the annual growth in the GDP, and this growth is expected to continue. It would therefore be reasonable to expect that a failure to meet electricity conservation targets may be attributed to the electricity consumption associated with the installation of new assembly lines and manufacturing processes, as shown in Figure 6.

The chemical industry accounts for approximately 20 % of the electricity consumption in the industrial sector. According to Energy Audit Database, most of the electricity is consumed in manufacturing processes (59 %) and air compressors (14 %) in the chemical industry. Again, this is where electricity conservation efforts will be focused. As shown in Figure 6, the major barrier to reaching mandatory target for chemical LEUs is difficulty in improving manufacturing facilities in the short term. In the chemical industry, the ratio of energy cost to total operating costs is high, and many of the utilities, such as air compressor and wastewater treatment, have already undergone improvements. The replacement of manufacturing facilities may be the best option to achieve further saving in electricity. However, the cost of replacing manufacturing facilities can be enormous; therefore, the chemical LEUs especially expect the government to provide tax preferences, as shown in Figure 7.

Figure 4 shows about 54 % of the LEUs in the iron and steel sector expect to achieve the mandatory target, which is significantly below the average among the various industrial sectors. As with the chemical industry, the major barrier to electricity conservation in the iron and steel industry is the inability to implement short-term improvements in manufacturing processes such as electric arc furnaces, integrated steel mills, and rollers. Savings would best be achieved through the implementation of induction heaters prior to rolling and the installation of high efficiency motors. However, improving manufacturing facilities cost a great deal of money. As shown in Figure 7, the iron and steel industry is expecting to receive considerable subsidies and tax preferences to facilitate electricity conservation.

In the cement industry, 63 % of the LEUs reported that they expect to meet the mandatory target, as shown in Figure 4. The processes that account for most of the electricity consumption are: grinding mills (46 %), cement raw material systems (23 %), and clinker systems (22 %) (Huang et al., 2016). To enhance overall energy productivity in the cement industry, the BOE implemented a standard related to the maximum energy consumption per product (specific energy use) for cement raw materials, clinker systems, and grilling mills from 2015. As shown in Figure 5, 65 % of the LEUs will be improving manufacturing processes through measures such as grinding aids for ball mills, setting vertical roller mills for finish grinding, or installing high-pressure roller presses. As shown in Figure 7, LEUs are seeking government assistance involving consultation and subsidies. The BOE has recently announced a program of subsidies for waste heat recovery facilities, and it may increase the motivation of cement LEUs to install the thermoelectric generator with waste heat recovery system in rotary kiln.

In the textile industry, 70 % reported that they expect to meet the 1 % electricity reductions, as shown in Figure 4. Manufacturing processes account for 62.5 % of the electricity consumption in the textile industry. As shown in Figure 5, 44 % of the textile LEUs will be looking for electricity savings by streamlining manufacturing processes. The BOE is planning to implement operating standards for textile chillers in order to limit the temperature difference between inlet and exit water in chillers. The ratio of small-medium enterprises in the textile industry higher is than that of other industries; therefore, the government will be expected to provide funding and consultation for electricity conservation.

LEUs in the paper industry are particularly optimistic about meeting electricity conservation targets. The major electricity draw in this industry are the paper machines and pulp preparation systems, which respectively account for 47 % and 21 % of the total. The BOE has implemented standards related to maximum energy consumption per product (specific energy use) for five paper types from 2015. As shown in Figure 5, LEUs in the paper industry will be seeking to improve energy efficiency through improving manufacturing process, such as upgrading of paper machines and pulp preparation systems. The paper industry will not only require subsidies and electricity conservation consultation, but will also expect BOE to provide best practice energy efficiency exemplars to the paper sector.

Conclusion

To avoid power shortages in coming years, the Taiwan government has set a mandatory target for electricity saving by 1 % to LEUs between 2015 and 2019. This mandatory target is implemented in combination with the existing energy audit scheme. Currently, the definition of LEU is based on energy consumption. LEUs are required to provide energy conservation plans in their energy audits, as suggested in the eceee report (Eichhammer and Rohde, 2016). In the future, Taiwan could seek ways to link the existing energy auditing scheme to ISO 50001 and to establish a verification mechanism, like the EU energy auditing scheme.

In Taiwan, electricity consumption in the industrial sector far exceeds that of all other sectors. This study used a questionnaire to investigate the industrial LEUs' attitudes toward man-

datory target. The survey results indicate that most LEUs will be able to meet the mandatory targets. Manufacturing processes generally account for the bulk of the electricity consumption; therefore, this is where electricity conservation efforts should be focused. With the exception of the electronic industry, major barrier to achieve mandatory target is that manufacturing facilities cannot be improved over the short term due to the enormous capital expenditures this would entail as well as the long depreciation period. Furthermore, a recent drop in energy prices has greatly reduced the motivation of LEUs to improve energy efficiency. Thus, the government should provide more subsidies or other incentives to promote electricity conservation over the short term.

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