A Comparative Study on Energy Assessment Data from Manufacturing Industry

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ABSTRACT

The Industrial Assessment Center (IAC) at West Virginia University has performed over 250 industrial energy, waste, and productivity assessments since 1992.This paper analyzes the data collected over the last two years, namely the 1999-2000 and 2000-2001 project years. A total of fifty assessment days were spent at manufacturing facilities during these two years and the data gathered and processed is subject to analysis. The drivers of the data were the SIC (Standard Industrial Code), recommended energy savings, the groups of Energy Efficiency Opportunities (EEO's), implemented energy savings, and the number of recommendations. The data analysis has revealed the nature of the significant EEO groups across a variety of SICs in terms of the potential for energy savings, specifically targeted towards selecting plant facilities for IAC assessments. Conclusions are derived regarding the most promising EEO's that can be determined based on the characteristics of the manufacturing plants visited.

Introduction

There are significant untapped opportunities to improve the efficiency of energy and other resource inputs to the industrial sector. Tapping these energy efficiency and conservation opportunities will enhance the industrial sector's global competitiveness while reducing its environmental impacts. Energy costs can be a significant component of operating costs in manufacturing. Performing energy conservation can reduce these costs. This is an important activity in terms of our national interests, especially in light of increasing energy costs. To ensure industrial competitiveness on a global scale, this is crucial (Gopalakrishnan, Plummer, Nagarajan 1997). Energy costs conform to a significant percentage of operating costs in a manufacturing industry. Operating costs can certainly be reduced by performing energy analysis and diagnostics, leading to efficient energy conservation and management policies.

In order to help industries identify and then capture EEM (Energy Efficiency Measures) and EEO (Energy Efficiency Opportunities), the USDOE OIT has supported the establishment of 26 Industrial Assessment Centers (IAC) throughout the US. The IAC's are located in universities and avail themselves of engineering students under the guidance and supervision of professors to conduct facility resource assessments. The assessments then help these industries identify measures they can take to harness EEM and EEO. The IAC at West Virginia University has been in existence due to funding from the US Department of Energy (USDOE), Office of Industrial Technologies (OIT) since 1992. The focus of the IAC has been towards reducing industrial energy consumption, mainly for small and medium sized facilities. The no cost industrial assessments performed by the IAC are available to manufacturing facilities in the SIC 20 to 39, provided that they have no in-house professional staff to perform the assessment, have gross annual sales below $ 100 million, have fewer than 500 employees at the plant site, have annual utility bills more than $ 100,000 and less than $ 2 million, and be located within 150 miles of the IAC. The energy assessment process includes the analysis of the utility costs and on site data gathering using effective instrumentation. The discussion with the plant personnel adds to the practicality of the recommendations and the use of the proper support data.

The industrial assessments performed during the recent two-year period (1999-2001) were distributed in the State of West Virginia and the neighboring States. This recent two-year period was considered, as it would reflect the variance in demographics with respect to the manufacturing sector, based on the nature of the facilities visited. A total of fifty assessment days were spent at manufacturing facilities and energy assessments were conducted. The literature was analyzed with respect to the type of research accomplished in the field of energy management. The references that would be useful to the reader to understand the various benefits and potential of effectively conducted energy assessments may be found in (Heffington et al. 1999; Lowenberg 1993; Dunning, Ward 1998; Teel, Wyland, Fossum 2000; Cerci, Yunus, Turner 1995; USDOE 1994,1998; McCoy, Rooks, Tutterow 1997). The energy conservation research performed in various industrial sectors on various types of equipment can be found in (Kueck 1998; Murthy et al. 1998; Heydt et al. 1994).

Manufacturing Facilities Visited

The SIC of the manufacturing facilities visited range from 2052 to 3714. Actual facility names cannot be revealed due to confidentiality constraints. A total of 33 SIC industries were visited during the two year time period (1999-2001). The nature of manufacturing activities were quite varied and included production systems pertaining to varied products such as soft drinks, asphalt paving, vitreous china, and aluminum extrusions. The plant site to be visited depends on the criteria set for the IAC program by the USDOE. The energy consumption is part of the criteria. Once the plant had been selected for audit process, the following elements were incorporated. Site visits were scheduled in advance and the total energy use as reflected on the customer bills was subject to analysis.

During the initial part of the site visit, discussions are held with the plant personnel regarding overall annual energy utilization, the manufacturing process, major energy consuming equipment, and specific and unique Energy Efficiency Opportunities that may not have been explored. The plant tour then gives the IAC team an insight into the overall manufacturing system and energy related aspects. The IAC team then begins to focus on priority areas that offer the greatest potential for energy reduction within the plant. The data is collected with the use of instrumentation and through effective estimation based on sound engineering judgment. The data analysis pertaining to each EEO is then developed into an assessment recommendation in the final report, showing the energy savings in MMBtu or kWh, demand savings in kW, energy cost savings, implementation cost, and simple payback on investment. The overall summary related to all the recommendations is also developed in the report.

Data Analysis

The results of 33 assessments done were analyzed to try to identify commonalities that could provide guidance to future efforts and similar industries on how to better use energy in their facilities. The data elements that were chosen for analysis were:

1. SIC of the facilities visited.
2. Recommended energy savings in MMBtu/year
3. Recommended energy cost savings in $/year
4. Implemented energy savings in $/year
5. The assessment recommendations divided into groups 1 through 8 as below.

- Group 1 – Compressed air systems,
- Group 2 – Boiler and steam system,
- Group 3 – Electrical motors,
- Group 4 – Heating, ventilation, and air conditioning (HVAC) systems,
- Group 5 – Insulation,
- Group 6 – Lighting,
- Group 7 – Waste heat recovery,
- Group 8 – Unique recommendations that do not fall into the above groups.

Examples of such recommendations include:

1. Energy recovery in hydrogen gas pressure reduction station
2. Set the energy savings option with office computers
3. Turn of dryers during break time
4. Install a backpressure turbine instead of the existing pressure reducing station
5. Energy recovery in natural gas pressure reduction station using Turbo-Expander
6. Use the existing saw dust boiler in cogeneration
7. Re-circulate molten metal in the electric induction furnace

Results

The results reported in this section and analyzed for trends presents an opportunity to understand the basic elements that may play a role in the energy consumption pattern within the domain of varied manufacturing facilities.

Recommended Energy Savings Across SICs

Figures 1 and 2 show the recommended energy savings in MMBtu per year and dollars per year plotted against the various SIC manufacturing facilities. In any particular SIC, the number of plants visited may be one or more. As can be seen on the figure, the SIC 2869, 2671, 3363, 3499, and 2421 are seen to have the most significant recommended energy savings in MMBtu per year as well as in dollars per year. The number of plants visited for these SICs was between 1 and 3. The SICs relate to industrial organic chemicals, packaging using paper and plastic films, aluminum die castings, fabricated metal products, and wood saw mills with kiln facilities.

The assessments focus on the large energy uses in each facility to identify the energy savings opportunities. Steam systems and compressed air systems form a predominant portion of the energy usage in the chemical industry, and are where most EEO's are likely to be found. The packaging industry that uses paper and plastic films is energy intensive due to the thermal processes inherent. The aluminum die casting facilities are energy intensive due to the metal melting and subsequent electrical motor loads associated with die movements. The fabricated metal products and wood sawmill facilities often utilize a large number of electrical motors. In the sawmills, it is not uncommon to see large horsepower motors being used for saws, shipper, debarker, and edger equipment. Figure 1 reflects the potential to determine EEO's in the 33 facilities studied in this research.

Figure 1. Recommended Energy Savings in MMBtu/Yr

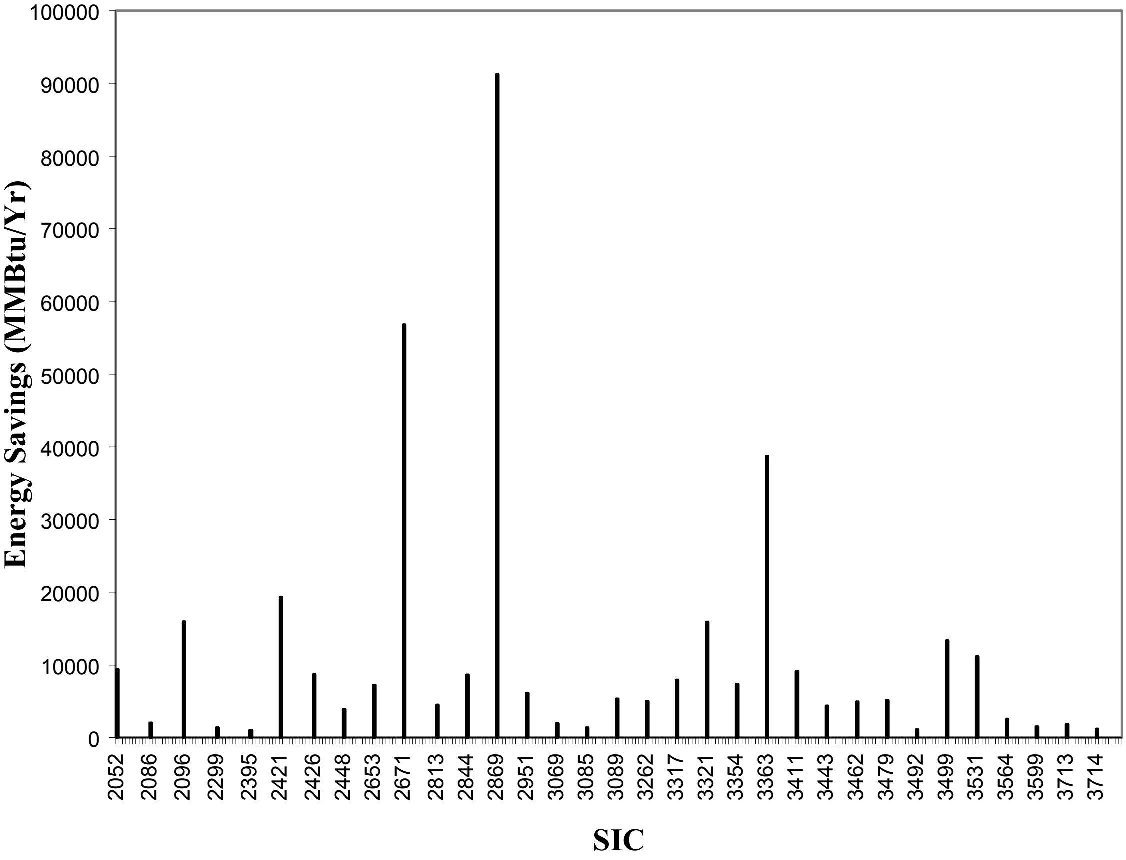
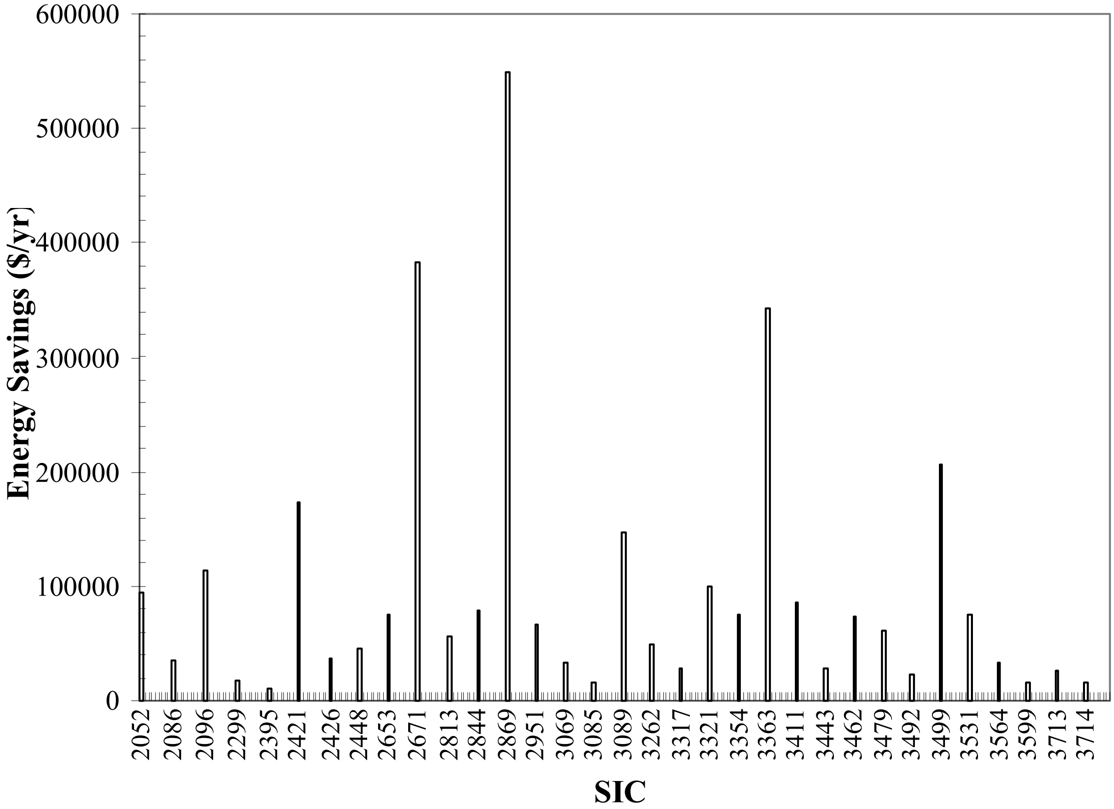


Figure 2. Recommended Energy Savings in $/Year



Energy Savings among Groups

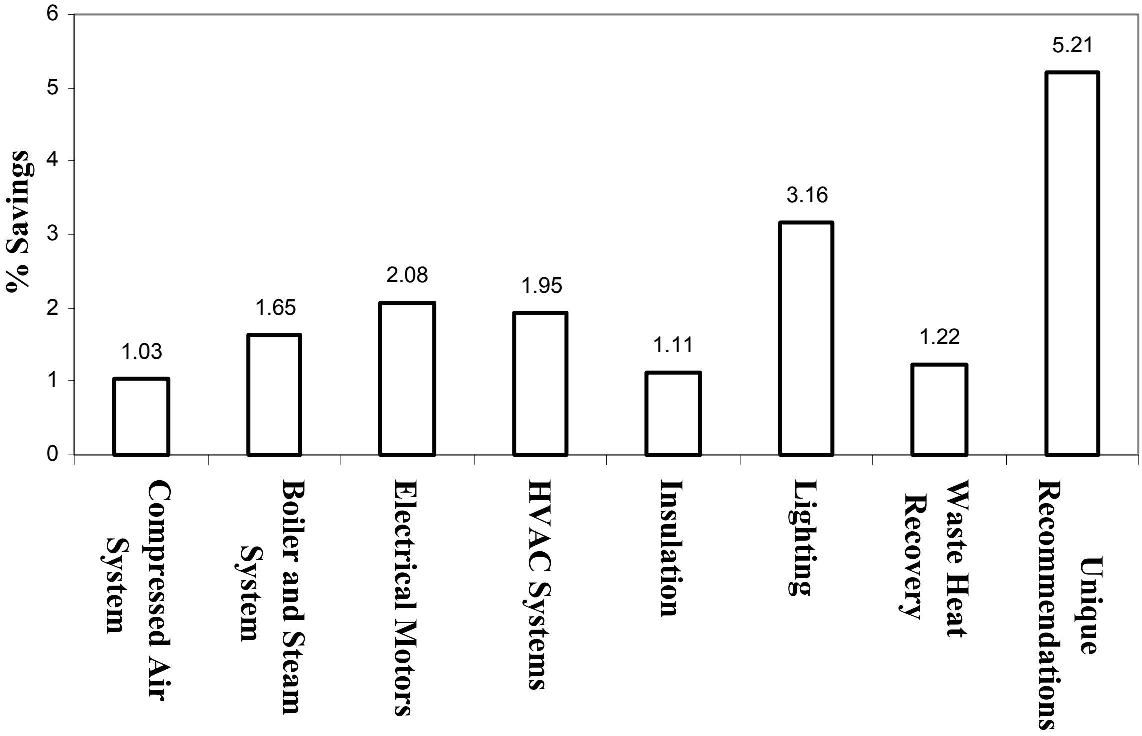
The table 1 shows the SIC with the largest recommended energy savings in MMBtu per year for each group. The saw mills (SIC 2421) show the largest recommended energy savings in compressed air systems. This is easily accounted for by the need for several compressed air driven actuators and mechanisms required for moving the wood raw material as well as the semi-finished products.

Table 1. Largest Recommended Energy Savings among Groups

Groups	SIC	Recommended Energy Savings in MMBtu/Yr
Compressed Air System	2421	2,382
Boiler and Steam System	2869	9,860
Electrical Motors	2671	6,351
HVAC Systems	2671	39,144
Insulation	2869	3,759
Lighting	2671	4,003
Waste Heat Recovery	2421	10,075
Unique Recommendations	2869	65,055

The chemical industry (SIC 2869) has significant recommended energy savings in boiler and steam systems and this is clearly understandable when analyzing the extent of steam required for processing chemicals. The packaging facilities (SIC 2671) reflect the largest recommended energy savings in the group related to electrical motors as these facilities employ a significantly large number of electrical motors for moving the products in position to facilitate effective packaging. The packaging facilities also have the largest recommended energy savings when it comes to recommendations related to HVAC. This is because of the need in such facilities to control the plant air quality and temperature as the quality of packaging (especially plastic films), largely depends on it. The chemical facilities can benefit significantly from insulating the steam pipes and hot surfaces. The packaging industry requires effective lighting for accurate inspection of finished goods and in process inventories, as reflected in them having the largest recommended energy savings in lighting. Waste heat recovery is particularly effective in wood processing facilities (SIC 2421) as many of them have wood burning boilers and dry kilns where opportunities for recovering the waste heat exist. The chemical facilities have unique EEO's in unique recommendations (other) as they use varied fuel sources and energy streams. The magnitude of recommended energy savings resulting from such unique recommendations is far higher than those for traditional recommendations because of the fact that the flow rates and utilization rates of the fuels and energy streams are quite high in chemical facilities. The figure 3 in the following page shows the average percentage of energy savings in dollars among each group to the total energy cost in dollars.

Figure 3. Percentage of Average Energy Savings to Energy Cost for each Group



Rationale for Making Inter SIC Comparisons

Although it may seem that inter SIC comparisons may not be appropriate as the industrial facilities being compared may have varying sizes and types of technology, it should be noted that the plants chosen are as per the IAC selection criteria set by the USDOE OIT. In general, the plants chosen for the IAC assessments are small to medium sized, hence leading to the result that the difference in sizes between the plants being not of significant nature. For example, the plants visited during an IAC assessment will not usually have differences in energy costs in the millions or square footage in the thousands. This is the reason that inter SIC comparisons can be meaningful, especially in the context of selecting plants for IAC assessments.

Implemented Energy Savings across SICs and Groups

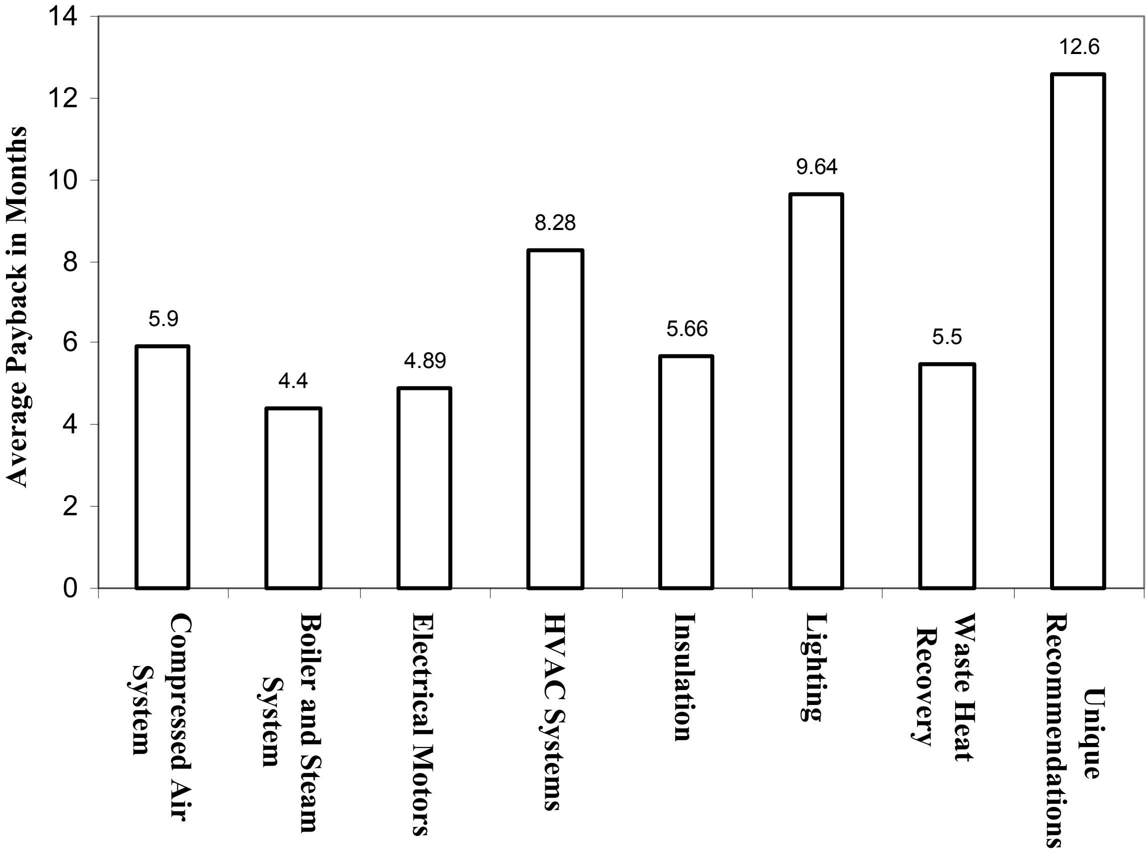
The implementation studies were done by contacting the facilities within six months of the date of the visit. It is interesting to analyze the data shown on Table 2 that tabulates the largest implemented energy savings SIC in dollars per year for each group. In terms of compressed air systems, the aluminum die casting facilities (SIC 3363) have shown significant interest in implementing these recommendations while the cookies and crackers manufacturing facilities (SIC 2052) have been interested in mostly implementing the boiler and steam system recommendations. These results can be explained by the fact that the processes in these facilities being somewhat automated leads to more attention being given to such utilities and the optimization therein. The packaging facilities have shown an interest in predominantly implementing motor related and HVAC related recommendations owing to the fact that the energy consumption in this area is often significant for them and their product quality often depends on this. The fabricated metal products facilities (SIC 3443) often have extensive metal treatment facilities that require heated fluids and hence piping; hence the interest in this sector. It is interesting to note that although the largest recommended energy savings in insulation was reported for the chemical facilities, the implemented savings are much smaller because of the concerns related to process quality and standards. The aluminum die casting facilities have shown good interest in implementing lighting recommendations mainly because the process is so well controlled that lighting does not necessarily play a major role in product quality and inspection as it may in other industrial sectors. The chemical facilities have shown interest in implementing recommendations on waste heat recovery, as the magnitude of gains can be quite significant. In chemical facilities, the waste heat often is required as input to another processes. However, many of these easy to implement opportunities are not being implemented in these facilities.

In this context, it can be said that such waste heat recovery opportunities are easy to implement than in other manufacturing facilities. The chemical facilities also have shown good interest in implementing unique recommendations because their processes are often tightly controlled and the unique recommendations are often non-process related but energy stream related. In an overall sense it is interesting to note the differences between SICs and groups when it is analyzed in terms of recommended energy savings versus implemented energy savings. The figure 4 shows the average payback on investment for improving the process to gain energy efficiency. The figure 4 shows the comparison between the various energy consuming equipment groups as pertaining to the attractiveness of payback on investment to realize the potential energy savings.

Table 2. Largest Implemented Energy Savings SIC in $/Yr

Groups	SIC	Implemented Energy Savings in $/Yr
Compressed Air System	3363	$22,500
Boiler and Steam System	2869	$50,000
Electrical Motors	2671	$62,900
HVAC Systems	3363	$66,000
Insulation	3499	$67,800
Lighting	2052	$70,513
Waste Heat Recovery	2671	$366,900
Unique Recommendations	2869	$396,500

Figure 4. Average Payback on Investment among Groups



Conclusion

The analysis of the data gathered from the energy assessments in manufacturing facilities has clearly revealed that the chemical, packaging, casting, and metal processing industries often have the largest potential for energy reduction, especially for choice as sites for assessment in the IAC program. The information presented in this paper is new contribution to the literature so as to guide plant managers, energy engineers and other personnel involved in the energy assessment process. Specific groups of recommendations have been analyzed and found to have promise in terms of development in particular SIC industries. The data analysis can pave the way for profiling energy intensive industries and reveal priority target areas in terms of minimizing the energy consumption.

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