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Study of Energy Saving Analysis for Different Industries

This study analyzes the energy consumption and saving performance in the industries in the U.S.A. All energy assessments implemented were for facilities whose annual energy consumptions were less than 9,000,000 kWh (small- and medium-sized industries) that belong to the manufacturing industries with Standard Industrial Classification (SIC) codes ranging from 2000 to 3999 in addition to SIC codes starting with 49. In this study, assessments are classified based on the SIC codes with recommendations analysis for each classification to get a better idea of what recommendations were suggested in each major industrial sector, knowing that 68 assessments were made, and their SIC ranged from 14 to 49. In addition, this study could be considered as a guide for energy engineers and other personnel involved in the energy assessment process. The information investigated can give a better prediction for composing better energy-demanding industries and minimizing energy consumption. More than 61 energy assessments were conducted for manufacturing facilities and analyzing the data gathered and processed. Through the research, the Fabricated Metal industry achieved the highest average kWh savings and cost savings within the industries studied in this study. According to the average gigajoule (GJ) savings, the fabricated metal industry ranked second within the studied industries. Conversely, Food and Kindred Products achieved the highest GJ energy savings within the studied industries. Lighting, motors, compressors, and heating, ventilation, and air conditioning (HVAC) were the most contributing industries in a total of 547 recommendations.
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Keywords: energy assessment, industries, energy consumption, energy savings, powers, alternative energy sources, energy conversion/systems, renewable energy

Introduction

There are four common resources for electricity generation in the United States, as per the U.S. Energy Information Administration in 2019, natural gas, crude oil, coal, and nuclear power. Figure 1 shows the net electricity generation in the United States in 2019. All electricity systems except for renewable resources can affect the environment and that includes greenhouse gasses emissions and other pollutants, the use of water resources to produce steam, thermal pollution, solid waste generation, and its effect on plants and animals. Most importantly, it affects human health [1]. With some fast-growing renewable resources technologies, especially for the last couple of years, such as wind and solar. A much smaller amount of electricity is produced through the distributed generation of technologies that generate electricity at or near where it will be used, such as onsite solar panels and combined heat and power. With natural gas still being the number one source for energy in 2020 and the minimal contribution of renewable resources, energy auditing should be taken into consideration to increase the efficiency opportunity and reduce the environmental effect on plants, animals, and humans.

The process of determining types and costs of energy use, whether in a building or a plant and identifying opportunities to reduce energy, is called an energy audit. Another definition of energy audit by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) is that it is a process in which engineering service providers identify and recommend efficiency opportunities to clients. There are four levels of energy audit ranging from zero to three, preliminary energy use analysis, walk-through analysis, energy survey and analysis, and the detailed analysis of capital intensive modifications, respectively [2]. Cagno et al. [3] categorized energy audits into three types, walk-through, mini-audit, and maxi-audit. Heras-Saizarbitoria et al. described three types of energy audits: walk-through audit, an intermediate audit, and an extended energy audit [4]. Generally, an energy audit has a wide range of auditing, starting from a simple on paper auditing and ending in a walk-through with detailed clarification.

Any energy program faces challenges, but the main one is always on how to increase the efficiency in all sections while keeping the price down with minimum cost and less environmental impact. In that case, it can be noted that efficiency takes care of the environment, health, and economy. As has been stated by the International Energy Agency, energy efficiency in the industrial sector can track energy consumption, which leads to determining whether the applied program is beneficial [5,6].

Many studies have shown the importance of the benefits of energy auditing. Mironeasa and Codina [7] and Schlüter and Rosano [8] focused on the cost-saving side of the benefits and how it reduces the energy cost. Sardianou [9] studied how energy audit has other noncost-related benefits, where his results support that qualified employees help in energy conservation. It is important to include human capital in industrial investments. Worrell et al. [10] showed how energy audit gives better working conditions and lead to improving products quality and enhance productivity. Mikulčić et al. [11] studied how energy audit reduces the cost of environmental compliance and raw material savings. Pye and McKane [12] studied the emission reduction caused by energy

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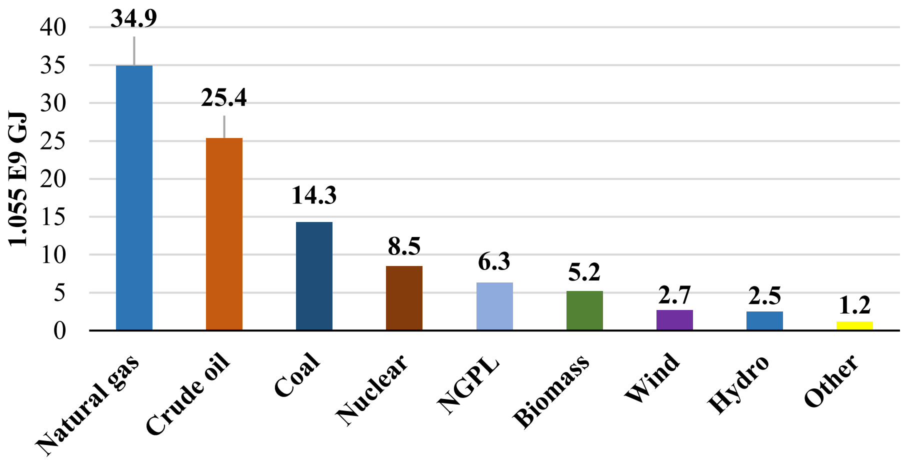

Fig. 1 Net electricity generation in the United States by source (2019)

auditing and investigated how it extends the equipment life span and reduce its maintenance requirements. Now more societies favor monitoring energy utilization and low carbon communities [13]. Grimm et al. [14] worked on an information technology infrastructure to control energy consumption.

Other researchers studied opportunities for saving energy and the use of renewables. The authors [15] investigated the feasibility of using hybrid photovoltaic (PV), fuel cell (FC), and battery system to power different load cases in Al-Zarqa Governate in Jordan, and it was found that the most suitable solution for residential buildings case is the PV–diesel generator system with battery, while the PV–FC–diesel generator–electrolyzer hybrid system with battery suites best both the school and factory cases. Kovalnogov and Chamchiyan [16] introduced PVC windows in microclimates to reduce heat loss in buildings. Dalzell et al. [17] gathered the data from the US census bureau, and the authors recorded and created a database for small and medium companies to establish energy metrics. Doms and Dunne [18] created models for energy intensity and consumption patterns for different manufacturing industries. Ladha-Sabur et al. [19] studied the energy consumption of the food industry to find whether food industries using thermal processes for production consume more energy compared to other food industries using nonthermal processes. Zhang et al. [20] studied a different industrial sector where he contemplated the energy loss detection and dynamic flow of materials for iron and steel manufacturers. Beyene [21] found that variable speed drives, compressed air systems, and combined heat and power (CHP) cycles had the highest potentials for energy savings after studying and analyzing the energy assessment recommendations for 300 companies in Southern California. Alhourani and Saxena [22] studied how much of the recommendations given were implemented in their assessments and called it the implementation rate, and what factors affected the implementation of the recommendations given through the assessments. The main purpose of the current research is to reduce the environmental impacts, the operating costs, and apply energy conservation as well as energy-efficient solution to have better renewable energy-oriented aspects and more reliable sources of energy to help any energy crises coming across.

In this study, all the assessments made by the authors in 4 years from 2015 to 2018 are classified by their Standard Industrial Classification (SIC). The SIC and the groups of energy efficiency have a hierarchical, top-down structure that begins with general characteristics and narrows down to the specifics. The first two digits of the code represent the major industry sector to which a business belongs. The third and fourth digits describe the subclassification of the business group and specialization, respectively; the type of manufacturing varies from the food industry, printing industry, and metal industry. Sixty-eight assessments were made between 2015 and 2018, and their SIC ranged from 14 to 49 with 547 assessments recommendations (AR) suggested. However, only 61 assessments were considered in this study; industries that received one assessment were excluded from this study. This study helps give a better prediction for future assessments and minimize energy consumption.

The Methodology of Data Analysis. The data gathered were analyzed to track the significant energy-saving opportunities among various industries for the 61 assessments that were carried out from 2015 to 2018. Such analysis can provide a practical approach and guidance for industrial facilities and future industrial assessments to recognize cost-saving opportunities. The outcomes of these assessments were evaluated in terms of cost savings and percentage of the type of recommendations conducted by considering the SIC code and the energy efficiency opportunities (EEOs). SIC grouping of the industrial facilities recommended energy cost savings per SIC group in US $/year, and the assessment recommendation grouping is the criterion that were used in analyzing the results of the assessments

Since the ARs in these 61 assessments are diverse, thus making the process of data analysis inconvenient, they were categorized as follows [23]:

— A. Heating, ventilation, and air conditioning (HVAC) systems
— B. Motors
— C. Compressed air systems
— D. Lighting
— E. Heat recovery systems
— F. Building envelope
— G. Electrical demand management and utility bills (EDMUB)
— H. Waste management and productivity enhancement (WMPE)

Group A recommendations include many ways to save energy by first replacing existing equipment such as boilers, chillers, and package units with higher efficiency ones; second repairing water and steam leaks in piping networks and valves; third changing or cleaning filters and repairing damaged piping and equipment insulation or insulate exposed pipes and equipment. Also, some of the recommendations suggest applying setback temperatures during unoccupied hours, turning off HVAC units when not needed and using radiant heaters for spot heating. Recommendations related to furnaces, boilers, and heating for processes are also included within this group. Some examples are as follows: analyzing the flue gas for proper air/fuel ratio, replacing fossil fuel equipment with a highly efficient electrical one, optimizing the heating temperature, and insulating bare equipment.

Group B deals with motors within the facility, whether used for HVAC systems, process, or water pumping. Recommendations are of replacing existing belts with V-cogged belts, using synthetic lubricants, and utilizing variable frequency drives where applicable. Also, replacing any old or oversized motors with energy-efficient and optimum-sized motors is considered for this group.

Group C recommendations are related to the compressor with reducing the pressure setting of the compressed air to the minimum required setting. Leaks of compressed air within the network are eliminated by even installing optimum-sized compressors and upgrading the controls of the compressor by using variable speed controllers.

Group D recommendations can be summarized by reducing the illumination to the minimum level necessary (de-lamping), utilizing highly efficient fixtures, and installing photocells and occupancy sensors.

Group E recommendations are recovering heat from flue gases to preheat combustion air, air compressors, and several types of equipment that were found within the facilities.

Group F recommendations are related to installing air seals around truck loading dock doors, utilizing vinyl strips or air curtains on doors, installing weather stripping on windows, and upgrading insulation materials used for walls and roofs.

Group G recommendations deal with limiting the nonurgent activities during the on-peak hours as well as installing capacitors to eliminate the power factor penalties on the utility bills. It also includes paying utility bills on time, turning off equipment when not in use or during breaks, and rescheduling plant operations or load reductions to avoid peaks in the utility bills.

Group H consists of waste management such as recycling water to be used for process cooling, minimizing water usage, and using a closed-loop where possible and contracting a wood pallet recycling company. It also comprises recommendations related to productivity enhancement corresponding to improving the space comfort conditioning, condensing the operation in one zone, upgrading or replacing equipment, and automating some processes to increase the productivity.

Energy savings can also be achieved without having a cost for implementation where the payback period can be immediate. Which can all be related to personal behaviors, reducing compressor discharge pressure, reducing the setback temperature during the unoccupied time are all example of such behaviors.

It is worth mentioning that some recommendations are considered best practices that tackle the environmental enhancement of the facility and is also considered part of energy auditing.

Results and Discussion

The results show data analysis of recommendations that were suggested for each SIC major industrial group as a percentage. Eighteen groups of industries were visited in all the 61 assessments. For a more fundamental understanding, the primary sector SIC code is included in parenthesis. Nonmetallic Minerals, Except Fuels (14), Food and Kindred Products (20), Lumber and Wood Products (24), Furniture and Fixtures (25), Paper and Allied Products (26), Printing and Publishing (27), Chemicals and Allied Products (28), Rubber and MISC. Plastic Products (30), Stone, Clay, Glass, and Concrete Products (32), Primary Metal Industries (33), Fabricated Metal Products (34), Industrial Machinery and Equipment (35), Electronic and Other Electric Equipment (36), Transportation equipment (37), Instruments and Related Products (38), Miscellaneous Manufacturing industries (39), and Electric, Gas, and Sanitary Services (49).

Five hundred and forty-seven (547) AR were suggested for all sectors. Figure 2 shows the number of assessments that were conducted from 2015 to 2018 for each sector.

Electric, Gas, and Sanitary Services (49) have the highest number of assessments of 13 showing how the wastewater treatment plants (WWTPs) were interested in energy auditing more than other industries, while Nonmetallic Minerals, Except Fuels (14) and Miscellaneous Manufacturing industries (39) have the lowest of a number of assessments of two.

Figure 3 shows the number of ARs that were conducted from 2015 to 2018 for each sector. Electric, Gas, and Sanitary Services (49) have the highest number of recommendations of 107 recommendations, and that is due to the number of assessments the that the authors conducted for that sector at that period, noting that many industries with only one assessment were not considered in this analysis.

Figures 4 and 5 show a comparison between different SICs based on the average energy savings achieved by each sector in kWh and GJ, respectively. Industries with SIC of 34 and 49 achieved savings of 1,534,000 kWh and 1,430,000 kWh, respectively, while that with GJ energy SIC of 20 and 34 achieved savings of 10,200 GJ and 7,900 GJ, respectively. The authors studied the possibility of introducing CHP to wastewater treatment plants holding the SIC of 49 to help save energy, considering that WWTPs have potential savings in both kWh in an indirect way and GJ [24]. Another energy-saving opportunity in WWTPs was studied by introducing hydro turbines to generate power and evaluating the power output to determine energy savings [25]. Energy consumption and energy savings are closely related. The more energy is consumed, the more potential there is for energy savings, and fabricated metal product industries holding the SIC of 34 is one of the largest industries. That explains their large consumption and thus

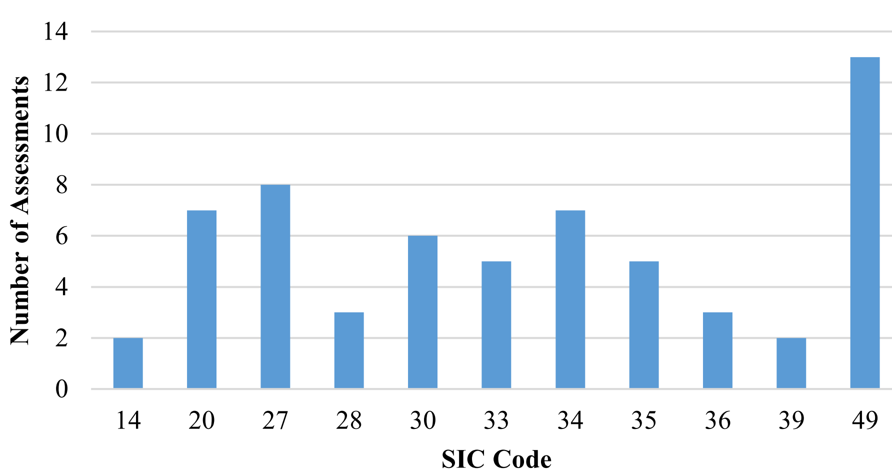

Fig. 2 Number of assessments for each SIC

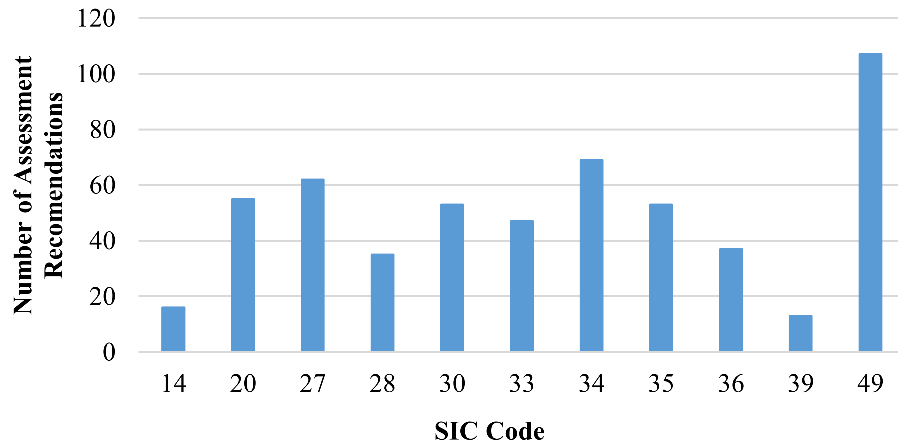

Fig. 3 Number of assessments recommendations for each SIC

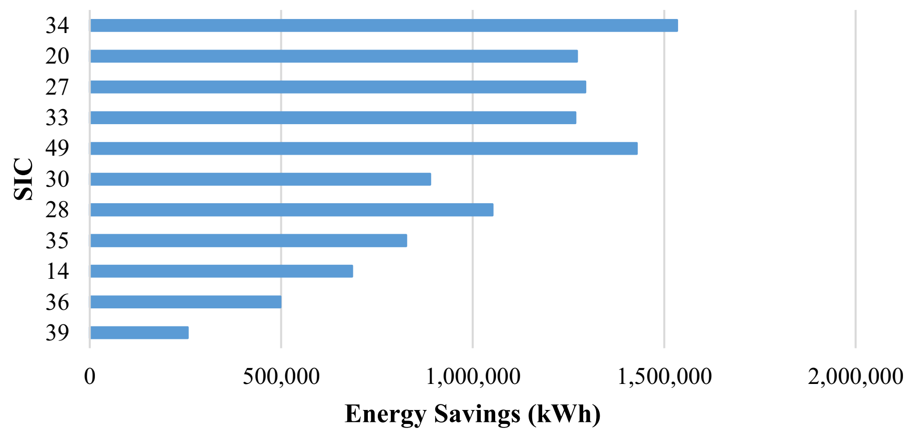

Fig. 4 Average energy savings in kWh

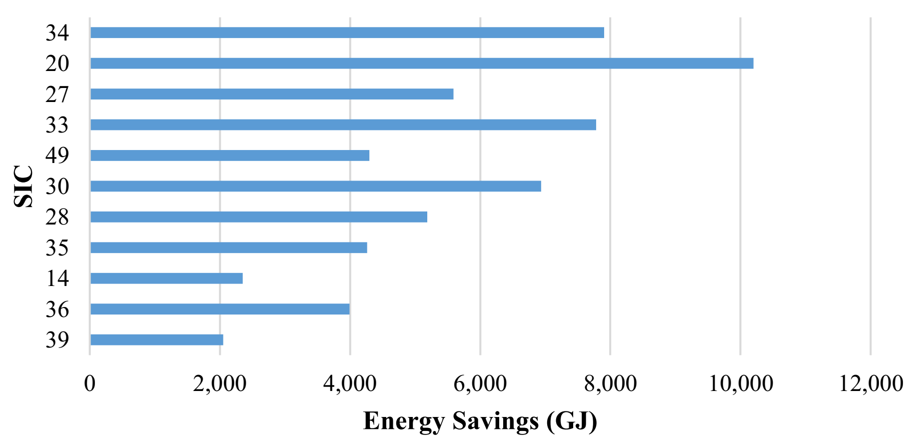

Fig. 5 Average energy savings in GJ

their highest potential for energy savings. The results obtained for both GJ and kWh were the average of the number of assessments conducted in the studied period.

In terms of cost savings, a comparison between different SICs is made based on the average cost savings achieved by each. From Fig. 6, it is noticeable that the industries with SIC of 34 and 20 completed the highest savings with an average of $142,390 and $137,790, respectively. Many factors affect the cost savings achieved in each assessment. kWh and GJ ratings are one of them. In this study, the energy savings were also averaged on the number of assessments. That explains that even though the 49 SIC industries had the highest numbers of assessment, the 34 SIC industries achieved the highest cost savings. Another reason is that industries like food industries with SIC of 20 use large equipment such as boilers, furnaces, air compressors, and refrigerators. These types of large equipment lead to several energy-savings

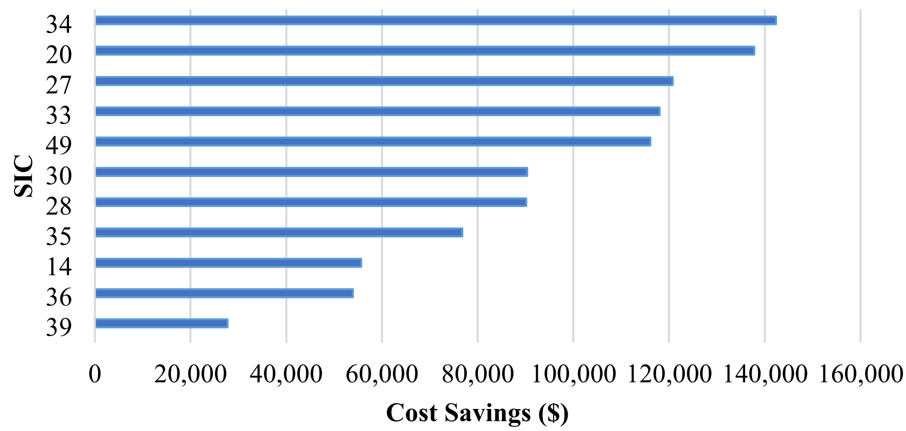

Fig. 6 Average cost savings in dollars

opportunities, thus more cost and energy savings. This fact reflects how much energy can be saved from such industries, and this might encourage the owners to audit their facilities.

Figure 7 is a good indication of how much kWh savings are represented in terms of percentage based on each SIC kWh Consumption Industries with SIC of 39 achieving the highest percentage in kWh savings with 28% compared with their consumption. Figures 8 and 9 represent GJ and cost percentage savings following the same trend as shown in Fig. 7.

Assessments recommendations are classified into eight different categories (as mentioned earlier) to know where the most significant opportunities for energy cut. Eleven assessments with 107 recommendations were made for 49 SIC, showing that motors' recommendation savings contribute 42% of the total savings followed by 23% for WMPE as shown in Fig. 10**.** Electric, Gas, and Sanitary Services that hold the major SIC of 49 requires the use of pumps, blowers, and motors as the main equipment in their main process operation. That explains the findings in this case study for

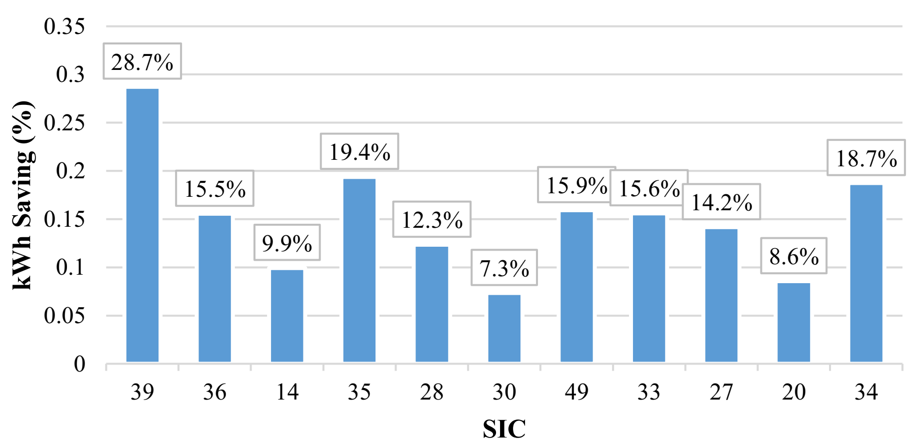

Fig. 7 Electricity kWh percentage savings

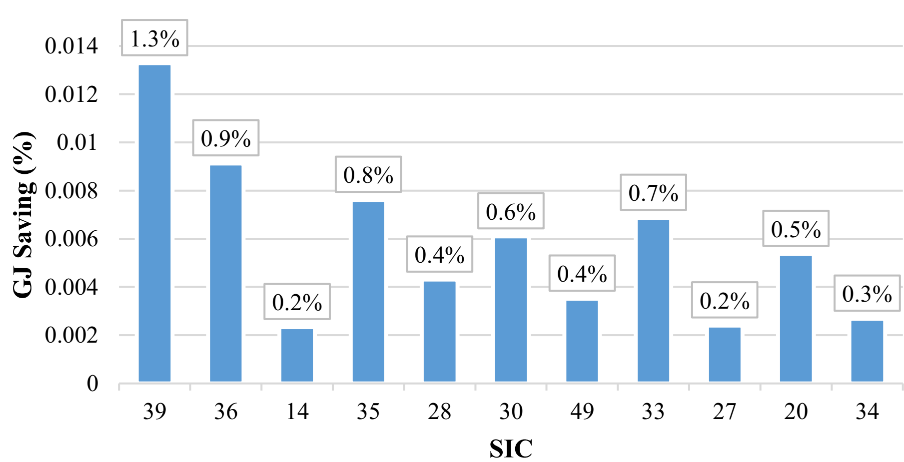

Fig. 8 Natural Gas GJ percentage savings

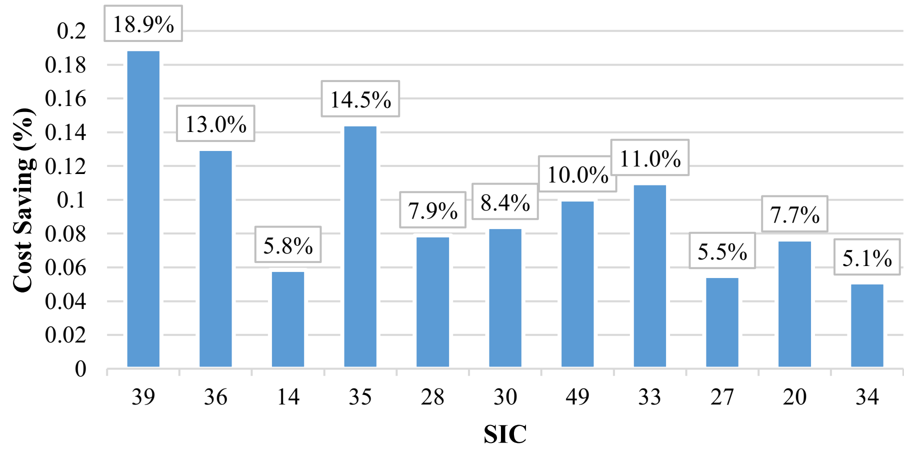

Fig. 9 Cost percentage savings

wastewater treatment plants of why motor contributed to the highest percentage savings. The authors also studied the energy consumption and energy savings in wastewater treatment plants, finding that using variable frequency drive on motors contributed to the most savings in energy and cost [26]. Also, waste management such as recycling water can help in minimizing water usage and enhances the environment [27]. (Similar charts for different industries can be found in the Appendix.)

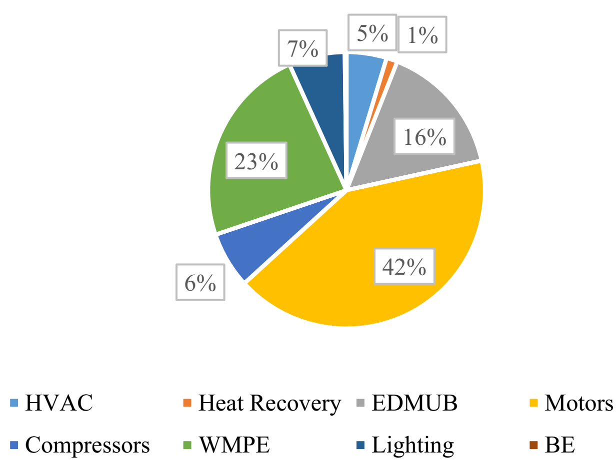

Fig. 10 Percentage of cost savings for SIC 49

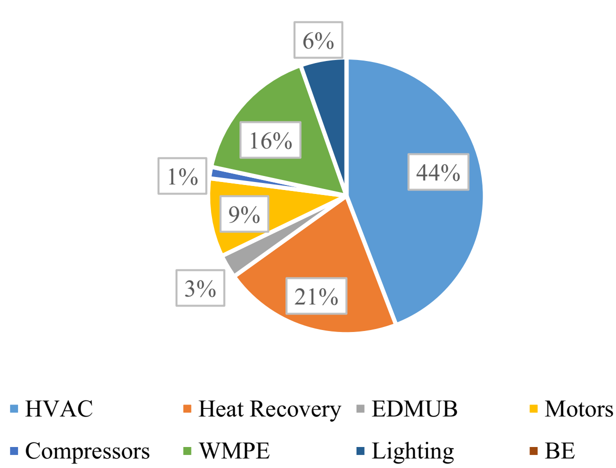

Fig. 11 Percentage of cost savings for SIC 33

Figure 11 also shows the percentage of cost savings. Still, for Primary Metal Industries (33), five assessments with 47 assessment recommendations were made, indicating that HVAC achieved the highest saving with 44% of the total savings followed by heat recovery with 21%. The primary metal industries' nature of manufacturing processes gives a higher opportunity for using heat recoveries and save gas consumption. Neri et al. [28] performed energy and exergy analysis for a high-demand energy aluminum factory that focused on heating process such as melting furnaces, heat treatment oven, and drying oven, and the analysis showed that a lot of energy was lost as heat to the environment, and waste heat recovery helped in saving energy. Also, with its strong demand to use HVAC due to the nature of the facility explains why HVAC has the highest savings opportunity. (Similar charts for different industries can be found in the Appendix (Figures 12–20).)

Conclusions

In this study, the data of 61 energy assessments were analyzed. Five hundred forty-seven assessment recommendations were suggested for different major industries. The larger the facility, the higher their consumption and thus the more energy efficiency opportunities to save energy.

Food and Kindred Products (20) require and use more natural gas in their manufacturing process, making their consumption of GJ higher than kWh and thus having more savings and the highest in GJ savings. However, the nature of Fabricated Metal Products industry (34) has high consumption in both kWh and GJ, giving them higher savings opportunity in kWh and GJ.

Fabricated Metal Products (34) and Electric, Gas, and Sanitary Services (49) achieved savings of 1,534,000 kWh and 1,430,000 kWh, respectively, while Food and Kindred Products (20) and Fabricated Metal Products (34) achieved savings of 10,200 GJ and 7900 GJ, respectively.

We have translated those energy savings into average cost savings while considering the rates of their energy consumption. Fabricated Metal Products (34) and Food and Kindred Products (20) achieved the highest average savings of $142,389 and $137,790.

These savings were compared with each SIC industry energy and cost consumption. Miscellaneous Manufacturing industries (39) achieved the highest percentage savings in kWh, GJ, and in terms of cost with 28.7%, 1.3%, and 18.9%, respectively.

Lighting, motors, compressors, and HVAC EEOs were the most contributing groups in a total of 547 recommendations. It is also noted that the lighting contribution of the 547 assessment was always 22% and higher. Still, in terms of energy savings, Motors, EDMUB, and Heat Recovery contributed to the highest percentage in almost all SIC's.

This study could be considered as a guide for plant managers, energy engineers, and other personnel involved in the energy assessment process.

Acknowledgment

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Conflict of Interest

There are no conflicts of interest.

Data Availability Statement

The datasets generated and supporting the findings of this article are obtainable from the corresponding author upon reasonable request. The authors attest that all data for this study are included in the paper. Data provided by a third party listed in Acknowledgements. No data, models, or code were generated or used for this paper.

Appendix

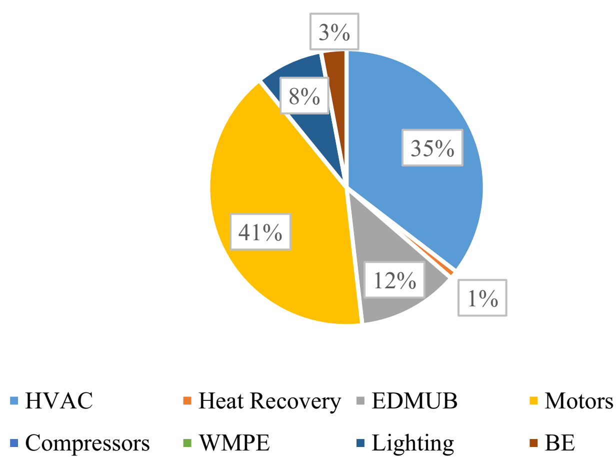

Fig. 12 Percentage of cost savings for SIC 14

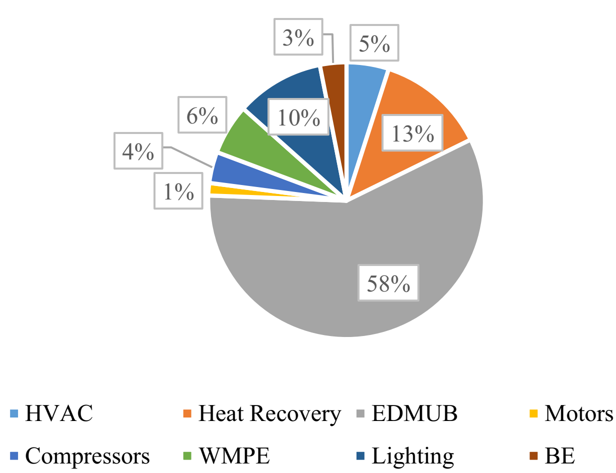

Fig. 13 Percentage of cost savings for SIC 20

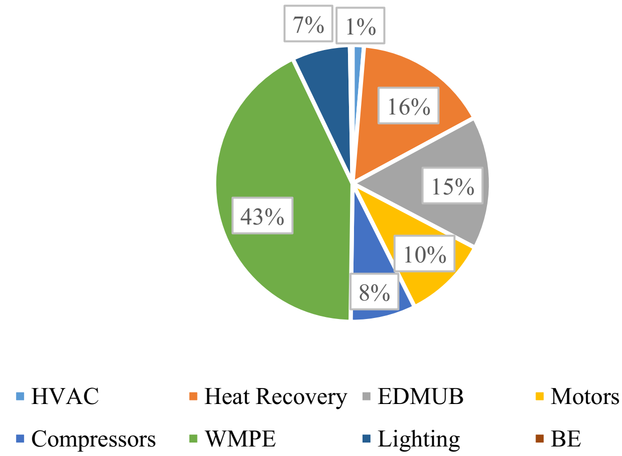

Fig. 14 Percentage of cost savings for SIC 27

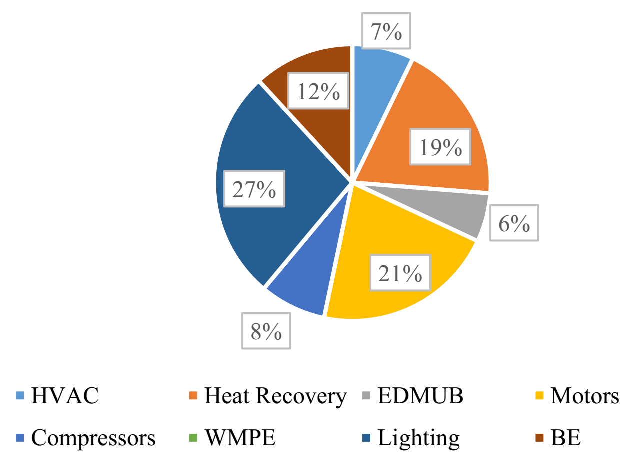

Fig. 15 Percentage of cost savings for SIC 28

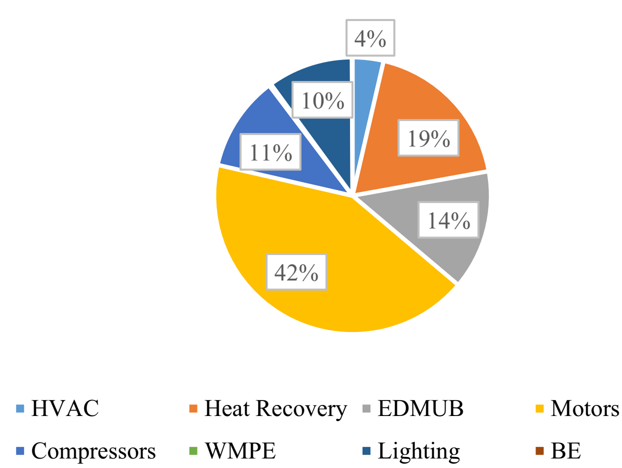

Fig. 16 Percentage of cost savings for SIC 30

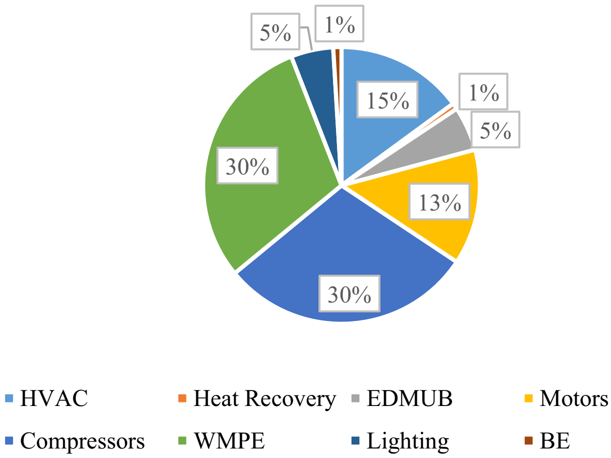

Fig. 17 Percentage of cost savings for SIC 34

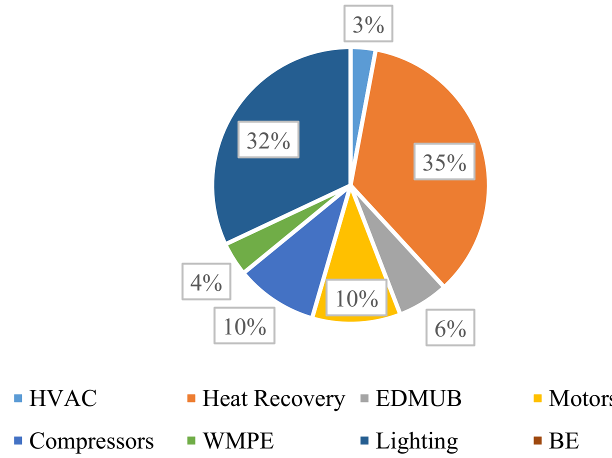

Fig. 20 Percentage of cost savings for SIC 39

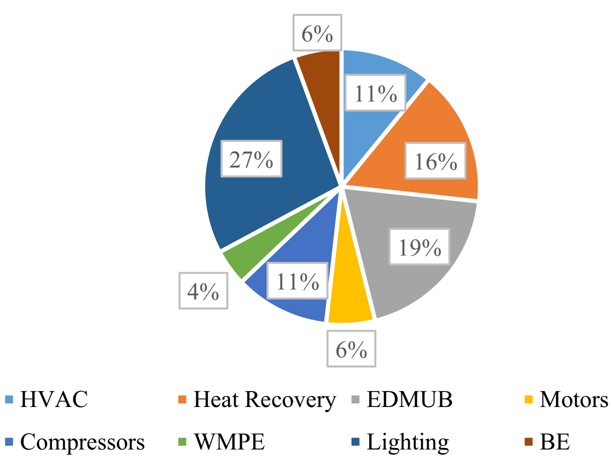

Fig. 18 Percentage of cost savings for SIC 35

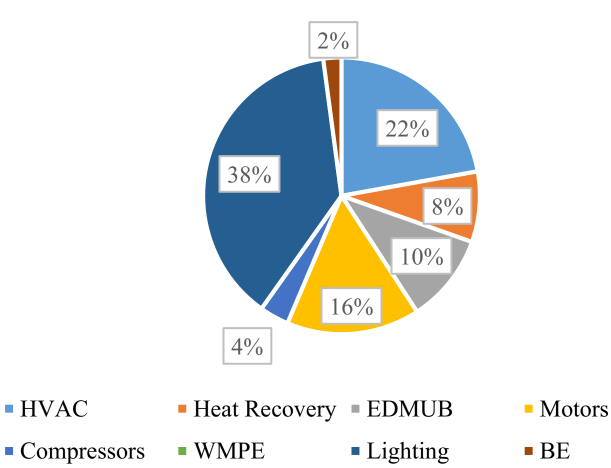

Fig. 19 Percentage of cost savings for SIC 36

References

[1] United States Environmental Protection Agency, 2020, "About the U.S. Electricity System and Its Impact on the Environment," https://www.epa.gov/energy/about-us-electricity-system-and-its-impact-environment, Accessed May 13, 2020.

[2] American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2004, "Procedures for Commercial Building Energy Audits 2004," pp. 5–9.

[3] Cagno, E., Trucco, P., Trianni, A., and Sala, G., 2010, "Quick-E-Scan: A Methodology for the Energy Scan of SMEs," Energy, **35**(5), pp. 1916–1926.

[4] Heras-Saizarbitoria, I., Dogui, K., and Boiral, O., 2013, "Shedding Light on ISO 14001 Certification Audits," J. Clean. Prod., **51**, pp. 88–98.

[5] International Energy Agency, 2016, "Key World Energy Statistics, 2016 Report," International Energy Agency (IEA), Paris, France.

[6] World Energy Council, 2013, "World Energy Resources: 2013."

[7] Mironeasa, C., and Codina, G. G., 2013, "A New Approach of Audit Functions and Principles," J. Clean. Prod., **43**, pp. 27–36.

[8] Schlüter, B. A., and Rosano, M. B., 2016, "A Holistic Approach to Energy Efficiency Assessment in Plastic Processing," J. Clean. Prod., **118**, pp. 19–28.

[9] Sardianou, E., 2008, "Barriers to Industrial Energy Efficiency Investments in Greece," J. Clean. Prod., **16**(13), pp. 1416–1423.

[10] Worrell, E., Laitner, J., Ruth, M., and Finman, H., 2003, "Productivity Benefits of Industrial Energy Efficiency Measures," Energy, **28**(12), pp. 1081–1098.

[11] Mikulčić, H., Vujanović, M., Urbaniec, K., and Duić, N., 2016, "Reducing Greenhouse Gasses Emissions by Ostering the Deployment of Alternative Raw Materials and Energy Sources in the Cleaner Cement Manufacturing Process," J. Clean. Prod., **136**, pp. 119–132.

[12] Pye, M., and McKane, A., 2000, "Making a Stronger Case for Industrial Energy Efficiency by Quantifying non-Energy Benefits," Resour. Conserv. Recycl, **28**(3–4), pp. 171–183.

[13] Lv, Y., Bi, J., and Yan, J., 2018, "State-of-the-Art in Low Carbon Community," Int. J. Energy Clean Environ., **19**(3–4), pp. 175–200.

[14] Grimm, C., Molina, J. M., Mahlknecht, S., Damm, M., and Lukasch, F., 2013, "Infrastructures and Platforms for Smart Energy Buildings and Neighborhoods," Int. J. Energy Clean Environ., **14**(1), pp. 21–39.

[15] Qandil, M. D., Abbas, A. I., Qandil, H. D., Al-Haddad, M. R., and Amano, R. S., 2019, "A Stand-Alone Hybrid Photovoltaic, Fuel Cell, and Battery System: Case Studies in Jordan," ASME. J. Energy Resour. Technol., **141**(11), p. 111201.

[16] Kovalnogov, V. N., and Chamchiyan, Y. E., 2016, "Development and Research of an Intellectual Power System for Controlling Microclimate in Buildings," Int. J. Energy Clean Environ., **17**(2–4), pp. 261–278.

[17] Dalzell, N. M., Boyd, G. A., and Reiter, J. P., 2017, "Creating Linked Datasets for SME Energy-Assessment Evidence-Building: Results From the US Industrial Assessment Center Program," Energy Policy, **111**, pp. 95–101.

[18] Doms, M. E., and Dunne, T., 1995, "Energy Intensity, Electricity Consumption, and Advanced Manufacturing-Technology Usage," Technol. Forecasting Soc. Change, **49**(3), pp. 297–310.

[19] Ladha-Sabur, A., Bakalis, S., Fryer, P. J., and Lopez-Quiroga, E., 2019, "Mapping Energy Consumption in Food Manufacturing," Trends Food Sci. Technol., **86**, pp. 270–280.

[20] Zhang, Q., Xu, J., Wang, Y., Hasanbeigi, A., Zhang, W., Lu, H., and Arens, M., 2018, "Comprehensive Assessment of Energy Conservation and CO2 Emissions Mitigation in China's Iron and Steel Industry Based on Dynamic Material Flows," Appl. Energy, **209**, pp. 251–265.

[21] Beyene, A., 2005, "Energy Efficiency and Industrial Classification," Energy Eng., **102**(2), pp. 59–80.

[22] Alhourani, F., and Saxena, U., 2009, "Factors Affecting the Implementation Rates of Energy and Productivity Recommendations in Small and Medium-Sized Companies," J. Manuf. Syst., **28**(1), pp. 41–45.
[23] Abbas, A. I., Saravani, M. S., Al-Haddad, M. R., Amano, R. S., and Qandil, M. D., 2018, "A Comparative Study of Industrial Energy Assessments for Small and Medium-Sized Industrial Facilities," ASME 2018 12th International Conference on Energy Sustainability Collocated With the ASME 2018 Power Conference and the ASME 2018 Nuclear Forum, Lake Buena Vista, FL, June 24–28.
[24] Nourin, F., Abbas, A. I., Qandil, M. D., and Amano, R. S., 2020, "Analytical Study to Use the Excess Digester Gas of Wastewater Treatment Plants," ASME. J. Energy Resour. Technol, **143**(1), p. 012104.
[25] Abbas, A. I., Qandil, M. D., Al-Haddad, M. R., Saravani, M. S., and Amano, R. S., 2019, "Utilization of Hydroturbines in Wastewater Treatment Plants," ASME. J. Energy Resour. Technol., **141**(6), p. 062011.
[26] Amano, R. S., Abbas, A. I., Al-Haddad, M. A., and Qandil, M. D., 2019, "Energy Consumption, Energy-Saving and Emissions Reduction of Wastewater Treatment Plants (WWTPs) in Wisconsin," AIAA Propulsion and Energy 2019 Forum, Indianapolis, IN, Aug. 19–22, p. 4239.
[27] Pawlak-Kruczek, H., Urbanowska, A., Yang, W., Brem, G., Magdziarz, A., Seruga, P., Niedzwiecki, L., Pozarlik, A., Mlonka-Mędrala, A., Kabsch-Korbutowicz, M., Bramer, E. A., Baranowski, M., Sieradzka, M., and Tkaczuk-Serafin, M., 2020, "Industrial Process Description for the Recovery of Agricultural Water From Digestate," ASME. J. Energy Resour. Technol., **142**(7), p. 070917.
[28] Neri, M., Lezzi, A. M., Beretta, G. P., and Pilotelli, M., 2019, "Energy- and Exergy-Based Analysis for Reducing Energy Demand in Heat Processes for Aluminum Casting," ASME J. Energy Resour. Technol., **141**(10), p. 104501.