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A Pathway Towards Sustainable Manufacturing for Mid-size Manufacturers

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Abstract

With growing public concern over the economic, environmental, and social consequences of climate change, it is crucial for manufacturers to focus on long-term sustainable development rather than short-term gains. While many large corporations have committed to sustainable manufacturing as a core component of their business, mid-sized manufacturers often lack the resources, motivation, and expertise to make this transition. Through progressive company culture, environmental and energy management systems, net-zero carbon, zero waste manufacturing, and life cycle thinking, this paper describes the necessary steps and benefits for mid-size manufacturers on the path to sustainable manufacturing.

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1. Introduction

According to the U.S. Energy Information Administration (EIA), industrial manufacturing is responsible for 30% of all GHG emissions in the U.S. [1] We define mid-size manufacturers based on manufacturer's total annual energy costs in this paper. Medium sized manufacturers are defined by having total annual energy costs between $100,000 - $2.5 million. Many large manufacturers with recognizable brands and access to capital have implemented sustainability initiatives to reduce pollution. However, mid-size manufacturers often supply products for larger corporations, and lack direct traceability between pollution and consumer products. Moreover, many mid-sized manufacturers have limited access to capital and experience fierce price competition to secure contracts. Enormous price competition and lack of public scrutiny limit mid-sized manufacturers' resources and motivation to prevent pollution. In many cases, the only incentives for pollution prevention initiatives are quick economic paybacks from resource efficiency projects [2].

There are large body of research published on developing a framework for sustainable manufacturing from various perspectives; large scale economic growth [3-5], policy development level [6, 7], life cycle and supply chain [8-11], production management [12, 13], product design [14, 15], process management [16-19]. Some researchers are focused on developing indicators for sustainable manufacturing [20-23]. However, industry case studies are rarely presented with a systematic level framework, especially for mid-size industries.

The University of Dayton Industrial Assessment Center (UD-IAC) has performed over 980 no-cost energy and material efficiency assessments for mid-sized manufacturers since 1981. Typical energy audit performed by third party consulting company puts financial burden to mid-size companies. UD-IAC has been developing a framework to provide no-cost sustainable manufacturing audits to identify savings on manufacturing cost, energy, and CO_2 emission through development of various methods described in this paper. In terms of plant energy efficiency, the efficiency measures we recommend typically reduce plant energy consumption by about 10% and payback within two years. For example, equipment lists and runtimes, together with regression-based utility bill analysis, can disaggregate energy data into energy systems such as lighting, motor, fluid flow, compressed air,

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process heating, steam, process cooling, industrial refrigeration, HVAC, combined heat and power, renewable energy [24-26]. This energy disaggregation permits comparison to benchmarks in the respective energy categories. The potential savings and cost effectiveness from savings in each energy category for each industry is thus estimable [27]. While significant, the results of these measures do not eliminate all negative impacts of mid-sized manufacturers.

The aim of this paper is to show how UD-IAC assists mid-sized manufacturers in reducing negative environmental impacts and achieving sustainable manufacturing throughout no-cost sustainability assessment framework described in this paper. Our work combines engineering and management knowledge along with practical energy efficiency and resource efficiency tool development then shared with industries. Unique tools developed for each stage of the frameworks are described with some case studies in the next section. The first step is to help developing a company culture that integrates sustainable values into the everyday activities of the company. The second step is to encourage mid-size manufacturers to establishes environmental and energy auditing for the implementation and promotion of sustainable values. The third step entails achieving net-zero carbon manufacturing (NZCM) through energy efficiency audit, net-zero emission electrical generation, and renewable energy certificates (REC). The fourth step entails achieving zero waste manufacturing by closing material loops wherever possible. The fifth step considers the entire product lifecycle from raw material extraction through the manufacturing process, use phase, and the end-of-life management offers much greater potential for sustainable manufacturing. While all five steps encompass economic, environmental, and social well-being, the first and second steps promote the successful implementation of the latter steps. After we go through this five steps with mid-size manufacturers, we provide a comprehensive final report which include all the assessment recommendation and calculation steps to improve sustainable manufacturing practices. More details about the framework are shown in the following section.

2. A framework for achieving sustainable manufacturing

2.1. Integrating sustainability into company culture: Step 1

High-level management must embrace long-term economic prosperity, including environmental and social development, rather than sub-optimum, short-term gains [28, 29]. In addition, companies must take responsibility for the full scope of their company's societal impact [30]. Over time, these values are instilled among all employees, providing long-term benefits to the success of the company. UD-IAC sustainability assessment audits have been most successful with companies whose high-level management value sustainability as a competitive strategy and key priority. Chief executive officers, vice presidents, and facility managers who participate in our assessments are enthusiastic about strategic opportunities that resource efficiency affords them as well as learning about societal and environmental benefits derived from reducing waste. Additionally, engaged employees combine their knowledge of their facility's processes with our expertise in resource efficiency, creating synergy between the two parties.

As a first step of our framework, we have developed a pre-assessment survey tool to collect data on a mid-size manufacturer's current status of sustainable manufacturing practice in different levels. It includes questions regarding on energy and environmental management, energy/material efficiency practices and on-going projects. We collect this information before we visit a mid-size manufacturer located in Ohio for a full day sustainability assessment audit. We use this information to discuss the company's current status of sustainable manufacture practices compare to the statistics of other the most recent visit of 15 manufacturers. This information is very useful to open up practical discussion about potential energy/resource savings opportunities in their daily production before we start physically investigating the plant for savings opportunities. We also encourage our clients to include chief management staffs to participate the opening meeting on the day of our sustainability assessment audits.

2.2. Energy efficient auditing systems: Step 2

Environmental and energy management systems (EEMS) are processes to implement, measure, and track progress in achieving environmental and energy goals. Some corporations may require original equipment manufacturers (OEM) to establish ISO certification before becoming an eligible supplier. However, some companies may believe that the costs of ISO certification, which include time, personnel, financial capital, and intellectual capital, outweigh the benefits [31, 32]. In addition, many companies perceive the certification processes to be overly complicated with an overemphasis on reporting rather than actual environmental development [33, 34]. Companies can create their own EEMS. Mid-sized manufacturers can incorporate sustainable values into their processes by applying EEMS in whole or in part. The underlying guidelines and principles of the ISO certifications can be adapted for mid-sized manufacturers, allowing them to reap the benefits without many of the obstacles. For example, both ISO 14001 and ISO 50001 follow the guidelines of the Plan-Do-Check-Act (PDCA) cycle. The UD-IAC assessment process follows the four steps of the PDCA. First, we create a baseline of material and energy use for the facility. The baseline assists in identifying waste throughout the plant and prioritizing projects. Second, we identify energy and material efficiency opportunities for the facility during one-day audit. After the facility implements these recommendations, the we track what recommendations were implemented and verifies savings from each recommendation. Finally, the UD-IAC hopes that plant personnel learn about resource efficiency best practices during the course of the audit and can continue to make improvements beyond the scope of the audit.

On that end, UD-IAC developed the Integrated Systems Plus Principles Approach (ISPA) for improving industrial energy efficiency that breaks complicated manufacturing processes down into distinct energy systems and four principles of energy efficiency. Energy systems include the electrical distribution, motor drive, lighting, fluid flow, compressed air, process heating, process cooling and space conditioning systems, from which virtually all manufacturing processes are comprised. The principles of energy efficiency are think inside out, maximize control efficiency, maximize energy effectiveness and analyse whole systems over whole time