This paper demonstrates how MES can help meet the challenges of sustainable production in addition to conventional uses. The methodology for extending the scope of MES to achieve energy efficiency and other sustainability goals is explained using standardized practices and actual installations.
Introduction
Manufacturing execution systems (MES) have evolved into a cornerstone of plant-wide automation schemes across a range of industries and manufacturing processes. Benefits of MES implementation include production increases, cost reductions, quality improvements, product tracking, data collection and regulation compliance, among others. While MES implementations have led to reductions in energy use and waste, the conventional focus of MES has been on production management.

Sustainability in Manufacturing
While the term sustainability can be used in a variety of ways, the most commonly referenced citing of this term can be traced to the United Nation’s Brundtland Commission. According to the Organization for Economic Co-operation and Development (OECD), the term sustainable development was introduced in 1980, and popularized in the 1987 report of the World Commission on Environment and Development. In the commission’s report, sustainable development was defined as; “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1].” Open to interpretation, ‘sustainability’ has come to encompass as much or as little as is required to fit the needs of its audience. For this reason, the definition requires further clarification to be applicable in manufacturing.

Since its introduction, organizations have tried to apply this concept to industry. One idea in particular the “triple bottom line” shown in Fig. 1 emerged as the business case for sustainability. This philosophy suggests a more holistic approach that relies on the principles of economic prosperity, environmental stewardship and corporate responsibility [2]. However, this idea, and the associated terms – ‘people planet profits’, ‘sustainable management’, ‘ecological sustainability’ – all have similar issues. Without metrics to define the achievement of sustainability, success in this arena cannot be measured.
Fig. 1. The triple bottom line (as adopted from the 2002 University of Michigan Sustainability Assessment) demonstrates the interrelationship of environmental stewardship, social responsibility and economic prosperity, and how they overlap to form a comprehensive definition of sustainability.

The idea of monetizing sustainability catalyzed the evolution of the triple bottom line into the Sustainability Ecosystem [3], shown in Fig. 2. These tenets, environmental compliance, communication and operational efficiency provide a measurable path forward that is supported by traditional business directives.

Fig. 2. The evolution of the sustainability ecosystem illustrates the balance of principles that can be measured or “monetized” based on outcome priorities and delivery of business performance.

Increased productivity, reduced plant operating costs, reduction in work effort and enforced compliance to government regulation have always been drivers that justify investments in plant optimizations. Taken on its own, each business directive can be related back to more efficient use of necessary resources – energy, raw materials, human resources, information, and equipment – which relates back to a measure of
efficiency. Taken together as an optimization strategy, a solution’s capability to meet the immediate needs of the plant has a positive impact on business in the future – not only for the company, but for future generations as well.

For example, the act of automating a manufacturing process to increase efficiency reduces cycle times, reduces human error and potential re-work, increases visibility of material flow and optimizes scheduling – all driven by economics. At the same time, these changes reduce energy expenditures, reduce labor – by reducing the use of gasoline consumption and capital expenditures such as office space and the energy required to power and heat them – and minimize scrap material, all facets of environmental stewardship. The data from these automation efforts has been traditionally used to make decisions on what to produce and when to produce it. But that data can also be used to make further cost reduction decisions, such as shifting production schedules to accommodate running in off-peak hours and potentially selling surplus energy back to the grid, forwarding the latest trend: corporate responsibility.

Today’s manufacturing solutions have been built to improve operating cost structures including load curtailment and shedding, generator control, HVAC control, thermal plant control systems, chiller plant control systems and energy monitoring. These traditional uses for manufacturing solutions were not developed based on the current trend of sustainability. Viewed from a different perspective, however, these types of solutions provide energy conservation and control, building and plant automation and electrical energy management solutions. Further exploration of how these conventional systems – and others – meet the goals of sustainability is explored in the following sections.

Manufacturing Execution Systems

While the term Manufacturing Execution System (MES) was coined by AMR Research in 1990, the MES concept has evolved for almost three decades from the development of advanced, computer information systems for manufacturing. In 2004, the global MES market crossed the billion-dollar mark, demonstrating the escalation in significance of MES to modern manufacturing operations [4]. Coupled with the growth in the MES market has been an expansion of the scope of MES systems, so that the definition on an MES from the Manufacturing Execution System Association (MESA) is now:

*Manufacturing Execution Systems (MES) deliver information that enables the optimization of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission-critical information about production activities across the enterprise and supply chain via bi-directional communications [5].*

The net result of this expansive definition is that MES now includes a powerful set of functionalities and optimization possibilities across industries and production environments.
The conventional role of MES has been to support various plant floor activities such as scheduling, order release and execution, quality monitoring and data collection. To provide such functionality, an MES typically interfaces with the automation and control systems and the enterprise resource planning (ERP) system, which is the software that manages business resources across the entire company. The capability of an MES to develop physical and logical links between the true business model and the manufacturing details creates the foundation of its power.

This combination can also provide many of the necessary tools to achieve resource efficiency and sustainability goals. Manufacturing companies face increased need to pursue these goals due to a host of economic, social and governmental pressures [6]. Rising energy costs alone could serve as justification to focus on energy efficiency measures for many manufacturing operations. Reducing energy usage and achieving other sustainability goals will require data connections across the production chain from process and product design to procurement, operations and control systems [7]. Because MESs already make such connectivity possible, they can serve as the backbone for companies to integrate energy and sustainability goals directly into their manufacturing operations. For the purposes of this paper, a variety of manufacturing solutions that might also be known by other names throughout the industry are included within the scope of MES so as to focus on the substance of the solution rather than the nuances of terminologies.

Overlap of Sustainability and MES

Worldwide, manufacturers are in need of adopting sustainability practices into process operations. The industrial sector consumes massive amounts of raw materials annually and a greater portion of the global energy supply than the residential, commercial and transportation sectors combined [8]. Such significant resource consumption makes the industrial sector perhaps the most important in terms of realizing potential benefits from pursuing energy efficiency and sustainability measures. Since their inception, MES systems have been implemented to improve resource utilization and efficiency. However, the final objectives of these implementations typically focus on plant-specific goals, such as reducing waste of valuable inputs and increasing machine uptimes, or achieving competitive business advantage [9]. Although these are powerful drivers, limiting MES systems to such narrow objectives fails to capture the full utilization benefits that these software systems make possible.

Viewing MES systems through the lens of sustainability – which by the broad definition used in this paper has a more comprehensive scope that includes environmental stewardship, economic prosperity and social responsibility – opens the door to much greater gains in resource optimization. MES systems allow users not only to use fewer resources but also to understand how those resources are being used throughout the production process. This is accomplished by providing “mission-critical information about production activities across the enterprise and supply chain via bi-directional communications [10].” This framework makes an MES ideal for improving resource utilization – not only in terms of using less material but also by providing better information on how those resources should be used. From this perspective, MES provides a system that is in place to help make the most efficient use of energy and raw materials and that is ready to execute before production orders are received.
A straightforward approach to achieving sustainability goals is through leveraging an existing MES’s functionality to manage raw materials and resources. Every industrial producer has different types of management needs for a variety of resources, such as energy, raw materials, water, air, gas, electricity and steam. Many manufacturers maintain a huge stock of raw materials and parts on hand of every kind needed to hedge against the risk of a shortage. This capital intensive approach is the result of inadequate information and planning capabilities and can lead to waste due to materials expiring, energy for maintaining storage and other forms of inefficiencies. A preferable approach involves using an MES that allows customer-specific business roles, such as first-in first-out, just in time, just in sequence or expiration-date based prioritization.

One case of utilizing an MES to achieve significant resource management gains involved a large Asia Pacific semiconductor manufacturer. Prior to the implementation, the manufacturer lacked the necessary information systems capabilities to efficiently use materials. This forced the manufacturer to identify maintenance problems reactively, order spare parts by phone and maintain a part inventory on a “just in case basis.” Once implemented, the MES allowed the manufacturer to capture data in real time, monitor specific machine conditions and execute proactive and preventative maintenance before failures occurred. By increasing visibility across all resources and facilities in the enterprise the manufacturer was able to achieve a more than 60 percent reduction in the number of spare part items [11].

Similar to managing raw materials, MESs are also capable of managing energy as a resource. For example, in the plant of one large brewing company rising energy costs became a serious problem as they started to significantly impact production costs. Although the plant had already attempted to implement some production optimization measures, energy efficiency still suffered due to constant machine breakdown, a lack of adequate spare part tracking, insufficient fault diagnostics and no historical process data. By implementing an integrated MES and control-system solution, the plant achieved major reductions in machine downtime and gains in productivity, ultimately leading to a 26 percent reduction in energy consumption [12].

But achieving efficiency improvements depends on more than just natural resource management – equipment management also factors into the equation. At the most basic levels of their functionality, MES solutions maximize resources. Many manufacturers maintain certain pieces of equipment dedicated solely to specific tasks. This manufacturing methodology results in energy and productivity losses due to underutilized equipment. By using an MES for effective order scheduling, manufacturers can minimize the number of times required for each operation and use the total equipment available in the most efficient way. This involves scheduling equipment resources dynamically based on an order’s requirements rather than maintaining dedicated equipment set aside only for certain tasks.

Automating process lines can make a significant impact on corporate responsibility initiatives to eliminate waste of resources. An MES system for advanced equipment management was installed at a U.S. plant belonging to a large beverage company. Prior to the system’s implementation, the facility was experiencing equipment interruptions and bottlenecks resulting in significant losses to the plant’s asset optimization and overall equipment effectiveness (OEE), which is a quantified measure of performance based on capacity, availability and quality. At the time, the facility used a pencil-and-paper-based system to collect line-performance data. The paper-based system was replaced by an
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MES and integrated with an advanced supervisory control and data acquisition (SCADA) system. The integration of the control system and the MES yielded high-quality data about the line’s operational processes. With access to the previously unavailable information, the operation boosted its production efficiency by 6 percent across the plant [13].

As control systems and MESs increase the amount of information available to manufacturers, data management will become a more important part of ensuring that sustainability goals are met. As already discussed, within the scope of the MES layer advanced data analysis tools drive process improvements and optimization efforts pertaining to resources and equipment. But data analysis tools in the MES layer can also drive regulatory compliance in industries that require detailed recordkeeping for traceability. Perhaps the best example can be found in the pharmaceutical industry, which is carefully regulated by the U.S. Food and Drug Administration (FDA) and similar agencies in other nations.

In Spain at a plant of a large pharmaceutical company, an MES was installed to pursue higher production quality and regulatory compliance. The MES scope included recipe creation and tracking, warehouse management, weigh and dispense human machine interfaces (HMI), electronic batch recording and bi-directional integration with an ERP system. While the flexibility of the MES did generate production and efficiency gains, for the life science company the principal benefit was the ability to track production records electronically rather than on paper. The electronic recording process allowed for higher quality production while facilitating regulatory compliance [14].

Similar to the requirements currently placed on life sciences companies, the onset of environmental regulations will increasingly create a need for manufacturing companies not only to provide data but also to analyze and properly report that data to government agencies. Many nations already require the industrial sector to report energy efficiency data [15]. Performance analysis and reporting functions form one of the core pieces of MES functionality so that with an MES in place, creating energy efficiency, emissions or environmental reports can be simplified by drawing from the data integration across plant information systems [16].

Gap Analysis and Recommendations
As discussed, MES systems provide a ready-made fit for achieving a broad array of sustainability goals. But just because MES systems can satisfy sustainability purposes does not mean that they are implemented with that intent in mind. In none of the cases reviewed were sustainability goals the reason for the use of an MES. Instead, corporate financial and production targets have remained the primary drivers behind MES implementations. Yet in the face of rising of energy costs, environmental-conscious consumers and increased environmental regulations, manufacturing companies are experiencing the need to pursue sustainability goals directly.

To adopt sustainability using the triple-bottom-line approach discussed in this paper, manufacturers need sustainability goals distilled into comprehensive metrics. Accomplishing this requires translating standard manufacturing concepts into sustainability-related terms. For example, reducing manufacturing costs translates to reducing waste; optimizing manufacturing agility translates to dynamic scheduling and ultimately to higher energy efficiency; adding traceability and regulatory compliance capabilities translate to higher quality products. In addition, all of these translations fall
under the broader sustainability categories of environmental stewardship, economic prosperity and social responsibility.

Making these goals into meaningful metrics, however, requires plant-wide integration that allows disparate data points to be aggregated and analyzed to become specific measures of quantifiable sustainability. Fig. 3 is an example of a system where the MES is integrated with other plant information systems, such as SCADA, OEE and energy management systems (EMS). The integrated communications structure allows the MES to analyze and report on sustainability metrics based on the company’s defined requirements. What makes this model of particular value is that many manufacturing companies already have this infrastructure either mostly or fully in place. So less capital investment is required to enhance the system to meet the sustainability objectives. This model promotes a solutions-focused approach that capitalizes on data from existing systems and uses it in more meaningful ways – lending itself to more creative ways of increasing efficiency – such as predictive modeling to meet increasing sustainable production goals.

As discussed, the most significant disconnect between sustainability requirements and existing MES functionality is that sustainability has not been a factor in the design and implementation of MES. By making slight modifications to the MES requirements, sustainability goals such as using less material and energy, reducing waste, recycling, increasing workplace and product safety or considering alternative energy, can be reached with existing MES systems. For manufacturers already pursuing or interested in sustainability initiatives, MES is an ideal tool for changing processes of production to meet the demands of such a competitive global landscape.
Meeting these demands in the long term will require that sustainability objectives are mapped into the existing structured methodology for developing MES requirements. Until then, it is clear that MESs have the capability to be used in the pursuit of sustainability goals with little or no modification. To better utilize this capability, manufacturing companies need to change their perspectives and roll sustainability goals into their MES functional requirements.

Reference
