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White Paper

Sustainability in Manufacturing

Leveraging the 4th Industrial Revolution to Reduce Emissions and Improve Health

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Executive Summary

The future of manufacturing is here and is needed now more that ever to help mitigate some of the major contributors to climate change that are associated with our market demands for both commercial and consumer products. We now have the knowledge and technology to vastly increase the productivity, precision, and performance of our industrial manufacturing facilities and processes in new ways that reduce energy and material use as well as GHG emissions. Still, policy reforms and the resulting adoption rates have moved at a relatively slow pace compared to the speed of technological innovation. To pave a path forward, we must take a comprehensive look at the industry's current challenges and solutions available today to accelerate change.

USGBC-LA believes the impact of integrating smart technologies into manufacturing operations, building infrastructure, and energy and water resources can substantially reduce waste and emissions, improve occupant and environmental health, and lower utility costs for manufacturers. Smart technologies can also better serve energy and water-efficient practices and contribute to improved indoor environmental quality. This white paper will showcase new best practices, and the tools, technologies, and programs that contribute to a greater sustainability impact in manufacturing. We will address methods to reduce energy consumption by looking at how energy-efficient technologies are measured and managed while encouraging manufacturers to identify synergies across system operations.

Introduction

Energy is one of our most vital resources, however, much of the energy we produce is lost through transmission, heat loss, and ineffective management. Importantly, energy is often the highest operating cost in manufacturing. In 2020, the industrial sector accounted for 33% of total U.S. energy consumption. Broken down by industry, mining, construction, and agriculture account for much less of annual energy consumption than manufacturing, which accounts for 77% of annual industrial energy consumption.[1]

California is the world's fifth-largest economy, and leads the nation in manufacturing gross domestic product (GDP).[2] As home to some of the largest industries–including aerospace, logistics, agribusiness, apparel, biopharma, and automotive–Los Angeles has the opportunity to lead by example and play a major role in transforming the manufacturing sector.

In large energy-intensive processes such as steel, cement, chemical, and oil production, directly addressing energy usage is clear. However, with over 300,000 small and medium manufacturers, the accumulation of process inefficiencies, faulty parts, and wasted materials leads to significant collective energy impacts upstream in the supply chain. Thus, it is imperative that manufacturers of every size play a role in reducing their consumption by embracing smart and renewable technologies.

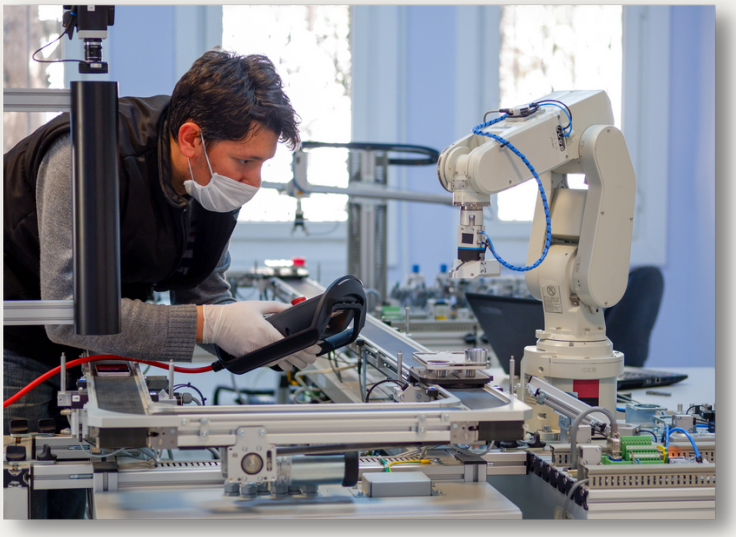
Smart technologies can be used to increase productivity, precision, and performance for every manufacturer, reducing energy loss. Operational strides in these areas also make diminishing environmental impacts and embracing sustainable practices more economically viable. These improvements not only decrease emissions to improve occupant health, but also increase product quality, cost per unit, competitiveness, and market share.

Industry 4.0

With the development and rapid evolution of information and communication technologies (ICT), the internet, enterprise resource management, and cloud and data management, we have entered the Fourth Industrial Revolution. Known by several names, Industry 4.0, Smart Manufacturing, or Manufacturing 4.0 is the movement we have seen toward smart automation, robotics, and autonomous systems in order to use our people and resources in far better, more diverse ways.

A new realm of innovation and opportunity comes with using data in smart ways. Industry 4.0 encompasses the use of wide-area networked-based communication, data exchange technologies, and cloud computing used in combination with IIoT, Industrial Internet of Things, to connect devices and people. When these are combined with data and modeling capabilities of artificial intelligence to build cyber-physical systems (CPS), we create the opportunity to measure, assess, predict, and take action at scales not previously possible. These cyber systems operate in conjunction with people to make decisions; taking action to control, optimize, and innovate–from a single component in operation, to an entire supply chain.

The Fourth Industrial Revolution offers strides in innovation, and limitless new solutions that are crucial to solving our climate crisis through the elimination of silos and the evolution of newly automated, renewable technologies. These solutions are driven by manufacturing demands for materials designed with purpose, products with greater precision made in smaller quantities, greater demand-dynamics response, and demand for global market share.



Smart Manufacturing

Smart Manufacturing is the technology, practice, change management, training, and business implementation of how to use data for productivity, precision, and performance of individual manufacturer operations, supply chains, and regional ecosystems. Smart Building technologies are often discussed separately, but are in fact the same, save for a specific focus on building infrastructure and the use of energy and water. Foundationally, Smart Manufacturing and Smart Buildings use interconnected real-time data leading to far better decision making and action concerning managing and controlling operations.

Despite automation's ability to make machines and humans work together to better manage an operation, there is still a need to assimilate new physical technologies into operational systems. Interoperability among operations and companies offer the potential for new collaborative business models, and supply chain visibility can lead to new market share opportunities for individual manufacturers and provide new ways to manage disruptions. But most importantly, the greatest impact on sustainability will be made through supply chain tracking and modeling for larger environmental strategies.

All of this depends on how cyber and physical come together on the factory floor and in building infrastructure. Advanced sensors, equipment devices, data, models, systems, controls, and equipment-based processes are the cyber and physical elements that make smart manufacturing actionable. Smart Manufacturing also merges the hardware, software, networks, platforms, and interfaces that collect and report data which increases scalability potential by forming a network of digital relationships that can be extended for line, factory, inter-company, supply chain, and ecosystem operations. Furthermore, it includes the use of modeling, analytics, and real-time data to monitor and inform decision-making. New opportunities are revealed once data roles are analyzed and decisions are acted on.

The Smart Manufacturing process is composed of three major steps: Measure and Analyze, Predict and Decide, and Respond. By capturing better data, we can anticipate circumstances to prepare and prevent rather than follow reactionary approaches. Manufacturers can accurately measure energy use across multiple system components to identify energy and resource losses in operations and to discover operational opportunities to maximize the use of energy. Operational opportunities include changing production schedules, optimizing across the collection of assets, ensuring greater uptime of operational equipment, predicting maintenance and operational health to further increase uptime, and monitoring quality during production to improve precision, reducing waste from non-spec products. This kind of smart optimization

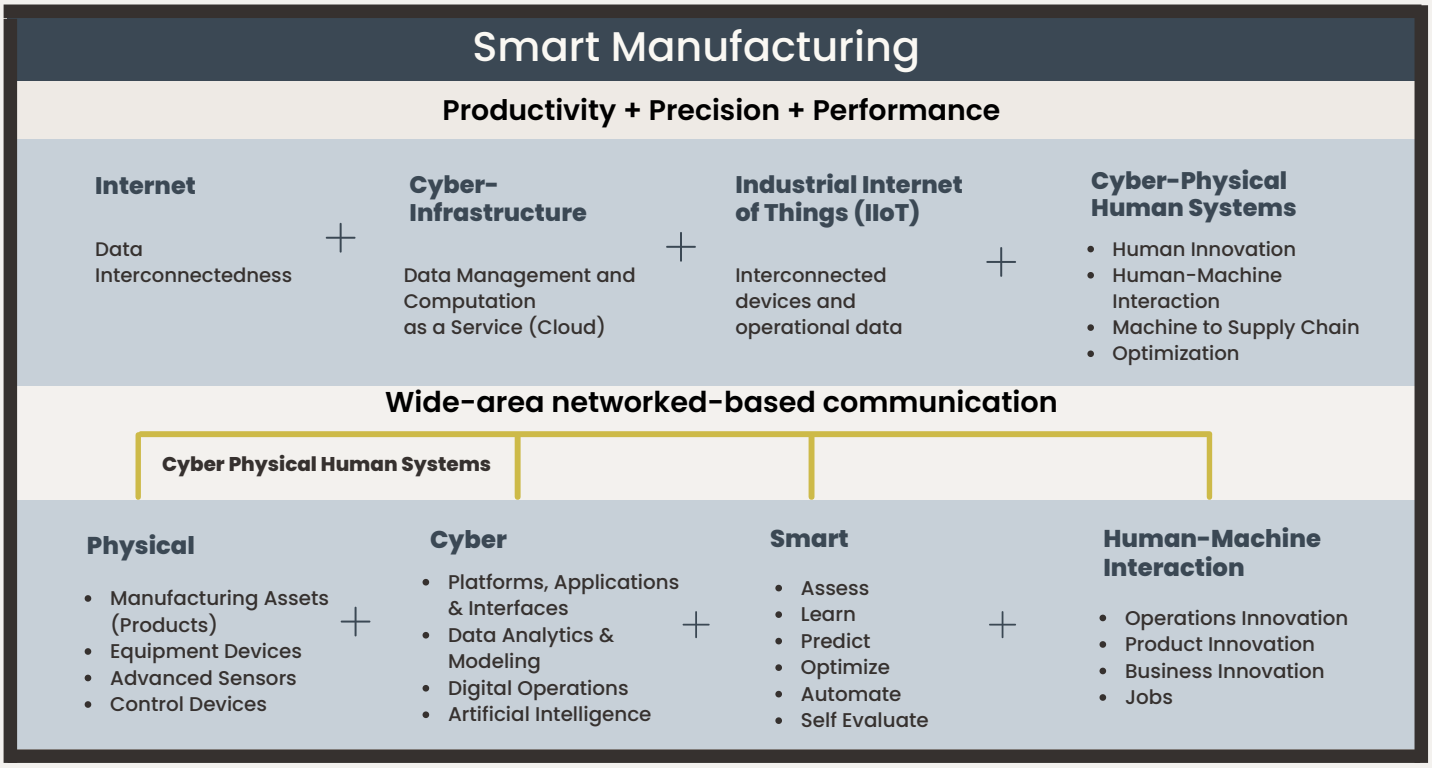
Smart Manufacturing

closes the longstanding gap among devices, systems, facilities, and people in an industry that has evolved in silos for many reasons. Smart Manufacturing introduces the ways to optimize across equipment operations horizontally where there are substantial new economic and sustainable opportunities.

Adoption Barriers

While the potential is high and the technology is available, market drivers, trade secret protection, legacy complexity, and legacy equipment loom large as barriers. Vendor markets currently value infrastructure compartmentalization of data, driving up the complexity, security, and cost of using data from multiple sources. Long-held views around protecting all operational data from any other uses lead to data that cannot be reused, one-off systems that are too expensive to sustain, and a lack of the right data and information for applications.

These factors reveal the need for better-trusted ways to rapidly implement legacy equipment and the need for business and technical tools that interoperate and share data in a trusted manner. The industry must view Smart Manufacturing not as removing jobs, but changing them. The future of Smart Manufacturing relies on a complex ecosystem of facility owners, operators, vendors, analysts, consultants, employees, and federal programs and regulations to align and interoperate technically and for business. As this alignment scales, it will directly impact how energy, water, and resources are managed.



Smart Manufacturing

Local Resources: CESMII

In June of 2016, the U.S. Department of Energy formed a public-private partnership to stimulate the adoption of Smart Manufacturing in the U.S. named the Clean Energy Smart Manufacturing Innovation Institute (CESMII). Funded with $70 million in federal funds and an expectation of $70 million in partnership contributions that can take many forms, CESMII's program home is at UCLA. There are seven Smart Manufacturing Innovation Centers (SMIC) across the country working in partnership regionally with manufacturers.

CESMII focuses on smart manufacturing solutions and practices, including enabling technologies, scaled and shared infrastructure, and workforce education and training. They are one of sixteen national Manufacturing USA institutes working in concert on different national priorities in manufacturing. The UCLA SMIC location is focused on demonstrating the use of shared data management and model-building infrastructure called the Smart Manufacturing Innovation Platform (SMIP). The SMIP is used for process and material operations and machine tooling operations, and lowers costs and accelerates the path to solutions by connecting, collecting, and contextualizing operational data, a capability that is common to all applications.

The UCLA SMIC sponsors industry focus groups on food and beverage, aerospace, and AI, works closely with the Department of Energy (DOE) Industrial Assessment Centers in the region, and works in partnership with California Manufacturing Technology Consulting (CMTC) in Torrance, the program home for the federal Manufacturing Extension Partnership Program in the State of California.

CESMII uses the concept of "Profiles" which are reusable and extendable information model templates for collecting data from common processes and machines.[3] These Profiles or information model templates describe how sensors, data, equipment, and processes relate to each other, eliminating the need to redo software development for each application. In providing the data foundations to "interoperability," the SMIP, when used in conjunction with Profiles, offers connectivity to different operational technology (OT) equipment asset sources, data capturing and secure data storage and management. The interoperability facilitated here makes it possible for OT components to interact with structured data that sets the pathway for OT components themselves to integrate. Most importantly, these Profiles are both adaptable and extendable for similar OT applications.

Today, CESMII has a portfolio of over 45 projects, of which 12 have concluded.[4]
The UCLA SMIC is overseen by Dale Turner (dale.turner@cesmii.org), who is also the CESMII Vice President for the CESMII's national SMIC network of resources.

Smart Manufacturing

Public and Private Partnerships (PPPs)

Investments in Smart Manufacturing technologies could add an estimated ten to fifteen trillion dollars to the global GDP within the next two decades.[5] Public and private partnerships (PPPs), like CESMII, will remain integral to facilitating growth in the sector by funding and participating in research, development, demonstration, and education projects. Manufacturers of equipment assets with OT capabilities, smart devices and sensors that connect through networks, telecom companies and network providers who provision scaled ICT and wired and wireless infrastructure, and the providers of operational solutions will be working toward common standards and protocols that are ultimately needed. PPPs are key to bringing these entities together with respect to business, technology, practice, and skills, playing key roles in reducing the manufacturing sector's carbon footprint by increasing the productivity, precision, and performance of supply chains.

Investing and expanding access to workforce training and education, along with technology solutions, will ensure a data-savvy workforce. From an energy and water standpoint, it starts with "measuring to manage." The ability to visualize how much, where, and when water, gas, and electricity are used can be a first step toward realizing the benefits of smart technologies for many manufacturers. In addition to platform integration, certain strategies and smart technologies, outlined below, can be implemented today to start the journey of applying data for operational optimization while moving toward new electrification technologies and renewable energy use.

Smart Sensors & Controls

Sensors are an integral part of smart manufacturing, as they have the important job of collecting and transmitting the data from a facility to a centralized platform for analysis. The falling cost of sensor technology is making the numerous types of sensors, including occupancy sensors, temperature sensors, and air quality sensors even more widely accessible. By adding connectivity and remote controls, these sensors can transmit data wirelessly and initiate actions from other equipment and devices in the building. A common example is the use of occupancy sensors to control plug loads. Using information obtained from occupancy sensors, smart plugs can automatically turn off plug loads when spaces are not occupied, so that appliances are not drawing electricity when not in use.[6]

Smart Sensing

Control Sensors
- Machine (e.g. Speed, Power)
- Process (e.g. Temperature, Level)
- Environmental Sensing (e.g. humidity, air quality)

Image, Movement, Sound Sensing
- Machine vision (camera)
- Vibration
- Acoustic
- Thermal imaging
- Composition imaging

Software and Systems Sensors
- Unmeasurable Product Properties
- Quality Sensing [in-process measurements of product attributes (dimensions, properties, surface)]
- Carbon modeling
- Hardware health
- Real-time KPIs

Human Input
- Manual Data
- Wearables
- AR/VR

In industrial settings, there are an abundance of options for smart sensors that can measure levels, vibrations, pressure, temperature, speed, power, proximity, heat, flow, fluid velocity, and even acoustics. For example, factories often use smart temperature sensors to monitor and prevent machines from overheating. Level sensors are commonly used in industrial environments and measure volumes of containers, bins, and tanks to give real-time information to inventory management systems and process control systems

By integrating smart sensors into a facility, building owners and facility managers can monitor data collected in order to make facility improvements. If enough data is available, artificial intelligence can be used to optimize building efficiency, using historical data trends to identify potential issues and make autonomous decisions on building operations. For example, sensors on plumbing fixtures can collect data on water use in a building, and artificial intelligence can identify patterns in water use, creating alerts when there are anomalies or potential plumbing leaks. As discussed in the next section, smart sensors can also be applied to HVAC systems to increase energy efficiency and optimize system performance.

Smart Sensors & Controls

Honeywell has recently completed a CESMII project on developing and applying Smart Manufacturing technologies for metal additive manufacturing.

Case Study: Data Modeling for Smart Aerospace Additive Manufacturing

Who: Honeywell & CESMII

Partners: UCLA, USC, Missouri University Science & Technology, Identify 3D, and Keselowski Advanced Manufacturing

Goal: Develop technologies on data modeling, machine learning, and data-centric analytics for metal powder-based additive manufacturing (3D printing)

Learn more about this Case Study and CESMII Projects here!

Process: Data was collected and analyzed for layer images, infrared thermal images, machine sensors, and part geometries. Use of both optical and infrared sensors to monitor each layer as it is sintered with lasers. Machine sensors typically included position, speed, and power.

Results:

- Additive manufacturing processing yield from 90% to 95%
- Reduction of energy consumption overall by 5%
- Developed predictive models for part support failure, energy consumption, and re-coater jam prediction
- Demonstration of advanced image processing and machine learning for process monitoring and anomaly detection

HVAC Efficiency

Case Study: HVAC Efficiency Projects in 3 Aerospace Manufacturing plants

Who: GREEN ECONOME

Where: Sylmar, CA

Problem: Demand charges reached peaks of over $16,000 per month for Plants 1, 2, and 3, which accounted for approximately 20% of the billed costs.

Process: Green EconoME identified lighting, HVAC, and thermostat systems that could be upgraded for financial and energy savings. They installed wireless, programmable thermostats that allow for remote control, and four HVAC units serving Plant 1 were replaced with smaller, more efficient units. They also hired IMS to perform HVAC Optimization Testing on ten HVAC units on Plant 1 after applying cleaning & replacement of HVAC units, improvements to ductwork, adding supply, return registers, and adding insulation to the roof piping.

Results:

- Saved the plant 18 tons of cooling annually
- Units performed 80% better than the Test In
- 151% more cooling was delivered into the space
- Addition of the Pelican Wireless Thermostat system further provides energy control

Smart HVAC systems provide invaluable data to building owners and help ensure buildings are operating optimally for energy efficiency and occupant comfort. A prominent use of smart HVAC systems is to better regulate the amount of conditioned air they provide to a space, based on information from sensors. These sensors can measure factors like carbon dioxide levels, occupancy, temperature, and humidity, adjusting operations accordingly. In doing so, the smart HVAC system is running more efficiently, reducing energy costs while also improving occupant comfort.

Advancements in cloud technology and remote monitoring allow owners to access and analyze real-time energy consumption and costs related to HVAC operations. Whereas previously, building owners had to wait every month to receive their utility bills, now they can use ongoing data to make operational adjustments and identify maintenance opportunities. In addition, smart HVAC systems have the capability to alert owners to unexpected jumps in energy usage and fault detections. Rather than waiting for scheduled maintenance to discover an issue, problems like leaks and blockages can be identified and fixed more quickly, potentially saving money on more serious system maintenance or replacement down the road.

Boiler Efficiency & Waste Heat Recovery

Heating is a basic necessity for industrial processes and occupant comfort, making it an indispensable part of the manufacturing process. A recent report published by the Lawrence Berkeley National Lab states that "in U.S. manufacturing, thermal processes account for approximately 75% of the total final energy demand, of which nearly 17% is consumed by conventional industrial boilers for steam generation in 2018."[7] Energy consumption, costs, and emissions can be reduced using high-efficiency commercial steam and hot water boilers, whose custom controls and sensors can make a major difference in manufacturing processes.

A boiler's efficiency is measured by its annual fuel utilization efficiency (AFUE), which is the ratio of heat output compared to total fossil fuel consumption annually. The Federal Energy Management Program (FEMP) suggests the use of boilers with a high AFUE (90% to 98.5%), and provides guidance on the acquisition of large commercial gas- and oil-fired low-pressure hot water and steam boilers.[8] Minimum efficiency requirements and thermal efficiencies can be found here, and non-federal organizations, institutions, and purchasers are encouraged to voluntarily adopt these practices. FEMP has performed extensive life-cycle analyses on the cost-effectiveness of commercial boilers and even has an Energy Cost Savings Calculator available to those deciding whether to retrofit or replace their existing boilers.

In addition to selecting a boiler with a high AFUE, several other factors should be considered when selecting the right boiler such as system size, peak heat demand, load capabilities, and facility characteristics, especially the quality of insulation at the facility and its relationship with the surrounding climate. Other energy-saving features to look for while selecting a new boiler include sealed combustion, low mass, water temperature reset, modulating burners, air-fuel ratio, optimum start control, and hybrid systems. Using multiple small modular boilers, in addition to boilers with modulating burners, can be useful when building energy loads are highly variable. Consistent maintenance is always recommended, including identification of leaks in duct systems and piping, combustion-efficiency testing, and installing smart sensors for ongoing monitoring.

Image via Shutterstock/Alexxxey
The interior of an industrial boiler room with three large boilers, pipes, valves and sensors.

Boiler Efficiency & Waste Heat Recovery

As renewable heat consumption increases, all-electric boilers and furnaces are a viable solution to mitigating heat loss and improving efficiency. The 2021 Lawrence Berkeley National Lab report projects the energy savings potential of electrifying industrial boilers to be "445 PJ per year of final energy, or 21% of the U.S. industrial boiler energy demand in 2018."[9] Manufacturers can take this a step further by transitioning to renewable fuel sources for energy (zero-carbon electricity).

A Mckinsey and Company analysis found that nearly half of all industrial fuel used for energy could be replaced with electricity using technology that is commercially available today. In some cases, electrification requires a fundamental change in the industrial process setup, but for equipment that requires heat up to approximately 1,000 °C, such as boilers and furnaces, replacement of individual equipment is sufficient to take the first step in transitioning from conventional fuel to all-electric equipment.

For example, on some industrial sites electric heat pumps and electric-powered mechanical vapor recompression (MVR) equipment for evaporation are already being used. For processes that require low to medium heat, partial electrification is possible with a dual or hybrid boiler setup, where steam production can alternate between electricity and fossil fuel use. Moreover, many new commercial boilers are equipped with smart sensors and have remote monitoring capabilities. Boilers with these features are recommended because they allow for remote management of operations, provide real-time performance feedback, and allow quick response times to malfunctions.

Waste Heat Capture & Recovery

Identifying ways to capture and recover waste heat is another critical component of energy efficiency. Heat generated during industrial processes is typically disposed of to the environment. Recovering heat waste through heat exchangers and economizers can provide a heat source to be reused in processes requiring input heat.

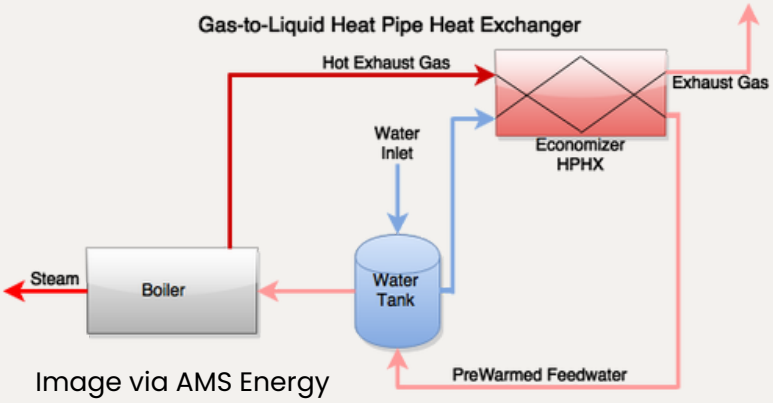


Image via AMS Energy Economizer Diagram

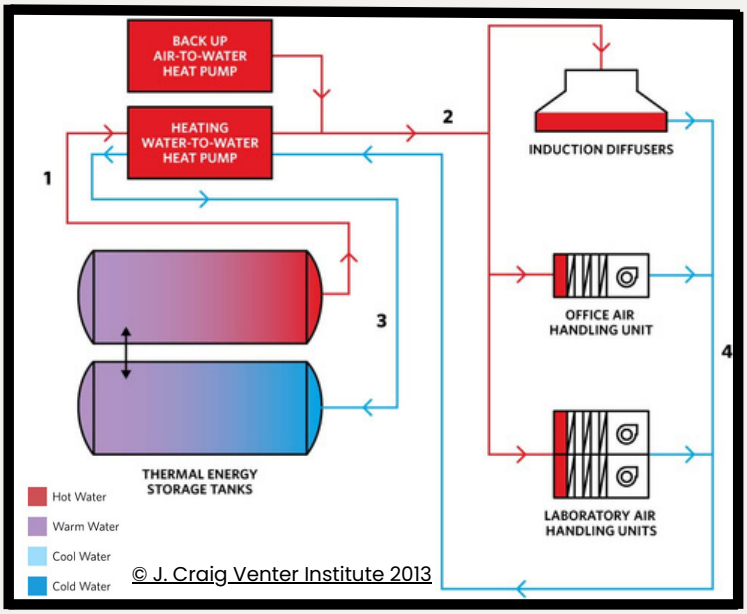
Boiler Efficiency & Waste Heat Recovery

Case Study: The J. Craig Venter Institute (JCVI) is a non-profit organization based in La Jolla that is engaged in genomic research and related fields of molecular biology. In 2013, owners came together with ZGF Architects to overcome the difficulty of designing and constructing a zero-net-energy laboratory.

The most notable design feature of the HVAC system is the installation of multiple thermal energy storage tanks for heat recovery and are combined with a water-to-water heat pump. The laboratory is just one component of the facility, and many other areas call for simultaneous heating and cooling so a cooling tower, heat exchanger, air-cooled chiller, and backup air-to-water heat pump were incorporated for operational adjustments.

The integration of these system components with the thermal storage tanks worked well in the La Jolla climate, as daily heating and cooling loads vary, and proved to offer a significant reduction in energy use.

Efficiency can also be improved by reusing heat from blowdown, returning condensate to steam boilers, or increasing boiler and pipe insulation.[12] If replacement is too costly, consider retrofitting current boilers and furnaces, as upgrades not only improve energy efficiency and reduce heat loss but can improve safety, as maintenance is often neglected for older systems. Retrofits are fuel-specific, so depending on whether a boiler or furnace is oil or gas-fired, different retrofits will be necessary. FEMP has more information on retrofits here, but ultimately the retrofit or upgrade to highly efficient boilers and furnaces can result in significant reductions in heat loss and therefore emissions.



Heating Process at JCVI

Renewables & Energy Storage

Fossil fuels are the main source of energy consumed for heat in industrial processes. In 2017, fuel used for energy in the industrial sector accounted for nearly 45% of total energy consumption, with 78% of this energy coming from fossil fuels.[13] Meanwhile, energy consumed from electricity comprised only 21% of total industrial energy consumption. Thus, it is imperative that industry shifts towards electrifying operations, which can be achieved in a number of ways.

Many manufacturers purchase electricity from utility companies or independent power producers, while some generate electricity for their own use, using purchased fuel or excess fuel created as a result of their industrial process. Some facilities incorporate the idea of "waste as energy" into their practices, for example, heat and power plants that burn fossil fuels produced in their mills to generate electricity and use as process heat. Other manufacturers utilize renewable energy technology like on-site solar PV systems, which has the advantage of allowing excess electricity to be sold back to the grid.

Though the initial investment into renewable energy may be considered too costly or unattainable for some, renewable capacity installations are at an all-time high and remain one of the most competitive energy sources due to decreasing costs of renewable resources, technological improvements, and increased interest in battery storage. Furthermore, emerging renewable sources and technologies like green hydrogen, advanced batteries, and long-term storage can provide zero-carbon electricity and ease grid congestion.

Case Study: Green hydrogen is able to provide long-term and seasonal storage of fuel available to generate power on-demand, and Los Angeles intends to become the first green hydrogen hub in an attempt to decrease hydrogen fuel costs. A new initiative called HyDeal LA, developed by the Green Hydrogen Coalition is working towards launching green hydrogen ecosystems which aim to halve fuel costs by 2030. HyDeal LA is working with LADWP on a project in Utah that will transform its coal-fired Intermountain Power Project into a combined-cycle gas turbine facility and will operate on 100% carbon-free green hydrogen by 2035, providing power to LADWP's service areas.[14]

Renewables & Energy Storage

In February 2022, the White House announced several initiatives aimed at reducing emissions in the industrial sector. One includes a 9.5 billion dollar investment into clean hydrogen technologies. Many industrial processes require high heat, currently produced with fossil fuels. Green hydrogen is created without emissions through a process called electrolysis, which separates water into hydrogen and oxygen. To seriously consider green hydrogen as a fuel and storage mechanism, and to lower the cost, we must expand our infrastructure. The White House is currently addressing this issue by funding regional hubs and investing in electrolysis R&D programs. The Department of Energy recently developed an initiative called Hydrogen Shot that aims to bring down the cost of hydrogen by 80% over a decade. Moreover, SoCalGas has proposed the largest green hydrogen energy infrastructure system, Angeles Link, which would deliver clean energy to the Los Angeles region, convert up to four natural gas power plants to green hydrogen, and eliminate up to 25,000 tons of nitrous oxide emissions.

As research and investments in green hydrogen are expanding, other reliable and well-known renewable energy sources like solar photovoltaic (PV) systems have seen an 85% cost decrease over the last ten years, making them some of the most cost-competitive energy resources marketwide. If on-site solar PV systems are paired with durable energy storage, system operations can become more efficient when linked, and cost synergies can be identified, including reduced storage costs with solar Investment Tax Credits (ITC). A recent Deloitte survey of more than five hundred U.S. executives found that 62% of the executives in the power and utility industry are either building or procuring grid-scale solar that includes storage.[15] Site owners should assess the potential to electrify, as the transition to renewable electricity presents wide range of potential financial benefits.

Even partial electrification, with hybrid or dual setups, yields financial benefits as a result of grid balancing practices, including lower prices when renewable sources are at peak production. This allows owners to receive payments from grid operators for consuming excess electricity produced during peak periods of renewable generation. During new construction and replacements, the installation of hybrid equipment early on in the decision-making process could make electrification more economically viable, as opposed to installing conventional equipment first and trying to switch to electric equipment in the future. Digital energy modeling can reduce rework when performed preceding the installation of any conventional, hybrid, or electric equipment by assessing relationships between existing equipment and predicting cost, time, and energy savings.

Renewables & Energy Storage

Depending on locality, manufacturers can also choose to purchase electricity off-grid from a nearby renewable production site, such as a solar or wind farm, to lower grid-connection costs.

Solutions for long-duration energy storage are critical to the integration and expansion of renewables into the electricity grid. Private investments in energy storage companies reached $650 million in August 2021 alone. In February 2021, an executive order was signed to strengthen domestic supply chains for advanced batteries and their materials.

Looking forward, electricity producers could assist industrial sites by delivering electricity directly to them, increasing the grid's renewable-generation capacity. What's more, renewable electricity generators could form a power purchase agreement that allocates any new renewable capacity to industrial customers. Ultimately, the future of renewable energy in the manufacturing sector depends not only on the accessibility and continual development of current technologies, but also on industry-wide adoption to improve the affordability of renewable energy. As the renewable industry continues to evolve and research into storage technologies grows, we expect to see synergies arise between new renewable technologies and energy storage.

Industrial Water Efficiency

Wastewater & Recycled Water

Every day, 18.2 billion gallons of water is consumed in the U.S. for industrial purposes. The EPA notes that industrial and manufacturing businesses use about 12 percent of the public water supply. Water is a valuable resource for industrial manufacturing facilities and should be used responsibly and sustainably to save resources and on costs.

Water is utilized in nearly every stage of production and across all industries during manufacturing processes. The byproduct, wastewater, can be toxic, flammable, corrosive, or reactive. Wastewater is often transported to off-site wastewater treatment plants where it is cleansed in compliance with national, state, and local regulations to maintain health quality standards. Untreated wastewater can enter waterways and pollute local bodies of water, posing a threat to environmental and human health.

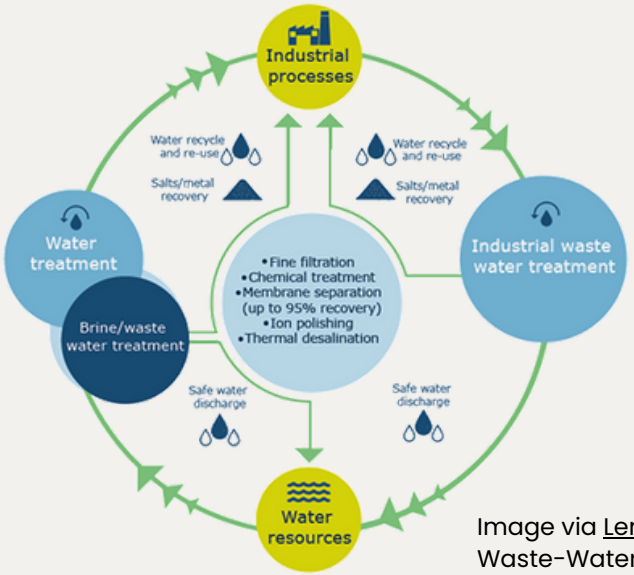


Image via Lenntech
Waste-Water Reuse

Companies that adopt formal wastewater management plans are able to reduce operational costs and increase profitability. Moreover, by investing in onsite wastewater treatment, companies can potentially reuse the treated water, decreasing the amount of wastewater discarded and new freshwater used. In the next white paper, Commercial and Industrial Water Reuse, we will review alternatives to conventional wastewater treatment and discuss technological advancements in water treatment and recycling.

Indoor Air Quality

Indoor Environmental Quality

Indoor Environmental Quality (IEQ) refers to the quality of conditions inside a building and its effects on occupants.[16] IEQ is a major component of the LEED rating system and consists of many different factors including air quality, smoke control, low-emitting materials, construction management, thermal comfort, interior lighting and daylighting, quality views, and acoustic performance. This section is focused on how indoor air quality, thermal conditions, and lighting within a facility affect occupants' health, well-being, and productivity.

Indoor Air Quality & Occupant Health

Indoor air quality (IAQ) is the "air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants."[17] Poor IAQ can result from the accumulation of indoor pollutants, which can stem from inadequate ventilation and high temperature or humidity levels. Poor IAQ can cause short-and long-term health effects for building occupants, while symptoms experienced can be confused with other illnesses, such as allergies and the flu. Frequent exposure can lead to other diseases, like cancer and heart disease, but a good IAQ will decrease the risk of employee injuries, adverse health effects, and contribute to a greater sense of occupant well-being.

Manufacturers should establish minimum indoor air quality standards in order to ensure the health and comfort of employees. In addition to meeting the requirements of ASHRAE 62.1-2019, outdoor air monitors should be installed with demand control ventilation, depending on whether the space is naturally or mechanically ventilated. Indoor air quality can be further enhanced by the installation of permanent entryway systems at exterior entrances. Dust collection systems such as grates, grills, and slotted systems can capture dirt and particulate matter entering the building and should be maintained weekly. For industrial processes that require hazardous gases or chemicals, cross-contamination can be prevented by sufficiently exhausting the spaces where hazardous chemicals are used. Self-closing doors and partitions can be used to prevent cross-contamination.

Indoor Air Quality

Case Study: High-performance installations play an essential role in controlling IEQ in manufacturing facilities. ASSA ABLOY's high-speed roll doors were installed by the A-Ware Food Group in its food manufacturing facility in Almere, Netherlands. These doors help isolate distinct areas, which protects unique processes and general workflow from affecting each other and causing contamination, ensuring good food quality. This case demonstrates a common but effective way of IEQ control and management.[18]

Since ventilation is necessary to improve IAQ, ventilation systems that filter outdoor air or recirculate air to an occupied space should have particle filters and air cleaning devices with a minimum efficiency reporting value (MERV) of 13 or higher. These filters should be regularly maintained and replaced. Furthermore, industrial dust collection systems are useful in removing hazardous particulate matter and gas fumes from the air. These systems include fabric filter baghouses, inertial separators, cartridge collectors, and electrostatic precipitators.[19] The specific type of collector should be chosen based on the type of pollutant. Other strategies to improve IAQ include installing operable windows in regularly occupied spaces to provide outdoor air, monitoring carbon dioxide levels with a CO^2 monitor, and other monitoring devices to detect specific contaminants.

Occupants within manufacturing facilities are frequently exposed to indoor air contaminants as the result of industrial processes. The implementation of an IAQ management plan is recommended during the pre-occupancy and construction phases, including protection of on-site absorptive materials from moisture damage. The accumulation of dust can breed bacteria and mold if exposed to moisture, which not only negatively affects occupant health but can also corrode certain equipment components. The last step in maintaining excellent IAQ is to carry out periodic assessments by performing flush-outs before and during occupancy, and conducting baseline air testing of particulate matter, inorganic gases, and volatile organic compounds.

High Heat Days

Los Angeles is no stranger to extreme heat days and severe wildfires, and these conditions will only be exacerbated over the coming decades with rising temperatures. It's important to consider how climate change will affect the manufacturing industry, the safety of workers, and the ability to create products and provide services. Following the home, the workplace is the primary location where United States residents spend their time. Workers in outdoor-setting industries, like construction and agriculture, as well as warehouse workers, are particularly vulnerable to the impacts of extreme heat.[20]

According to the U.S. EPA, "heat is the leading weather-related killer in the United States," resulting in approximately 600-1,300 deaths annually.[21] Moreover, a study from the University of Chicago demonstrated that people become less productive when exposed to high temperatures.[22] In addition, they found that workers in plants with climate control were more productive, but that climate control alone does not reduce absenteeism. As stated by Cal OSHA, California employers are required to take three steps to help prevent heat illness actively: training employees about heat illness prevention, providing water and access to shade, and developing and implementing a heat illness prevention plan.[23]

Employers can prevent heat illnesses in indoor and outdoor workplaces by assessing the location and its associated systems, the equipment and clothing worn by workers, and rest times and exertion levels. With rising temperatures becoming a significant problem for the manufacturing industry, business owners should invest in interior climate control as mentioned in the HVAC Energy Efficiency and Indoor Air Quality sections. Other intervention strategies include mandated rest time and continuous monitoring for heat illnesses.[24]

In indoor settings, besides providing air conditioning, implementing passive design techniques within the built environment can improve indoor air quality and reduce the reliance on the HVAC equipment for cooling. Passive design strategies are typically developed and planned early on in the design of facilities, however, certain upgrades and retrofits can prevent building heat absorption, for instance: assessing insulation strength, installing double-pane windows with low E glass, air sealing, and cool roofs. These facility and equipment upgrades, along with intervention methods and training, will help prevent high-heat days from impacting worker health and retention, in addition to subsequent supply chain issues.

Lighting Efficiency

Lighting, because it contributes so heavily to working conditions, acts as one of the most indispensable parts of indoor environmental quality of manufacturing. As companies seek high efficiency, low cost, and sustainable practices, lighting system upgrades pose significant benefits. Various protocols and regulations have been implemented to encourage environmentally-friendly facilities, leading to high demand for lighting innovations.

For its cost-effective, flexible, and less power-demanding characteristics, LED has been proven as an ideal replacement for traditional lighting fixtures.[25] Furthermore, studies have shown factory lighting's positive effect on workers' morale, safety, health, and productivity, as well as providing a more conducive environment for quality checks.[26] In short, lighting upgrades not only support the manufacturing process and ensure good production with limited energy and resources, but they also help protect workers' wellness, building a positive, sustainable environment for the company.

Lighting upgrades matter, but smart lighting upgrades matter more. A common approach is simply substituting traditional lighting equipment with equivalent LED fixtures, which can be easily achieved, but this is not a guaranteed solution to balance energy saving if other aspects are not considered. Lighting improvement is not just a simple fixture replacement, but an overall facility upgrade related to numerous aspects that require comprehensive procedures. When selecting lighting, it is important to assess several factors: measuring the needs and setting goals for the lighting system, reviewing the guidelines and codes on industry standards, considering practical conditions in all-day-long operations under different weather and temperatures, combining various methods (i.e. daylight capturing and color temperature control) for the best solution, integrating control systems (i.e. sensors or dimming technology) properly to boost energy efficiency, and investing in LEDs with good quality and performance.[27]

Occupancy sensors, in combination with lighting controls, are a common application of smart sensor technology. Based on whether a space is occupied or vacant, the sensors will turn the connected lighting fixtures on or off. Manufacturing facilities often require high levels of lighting, which means these lighting controls can offer significant and relatively simple energy savings.

Lighting Efficiency

Case Study: In 2016, Green EconoME, a full-service energy consulting and construction company, worked together with a local aerospace company to assess the energy efficiency of current operations and equipment in two of their aerospace manufacturing building. The high peak demands at the facility were a pressing issue. In 2015, demand charges reached peaks of over $16,000 per month for Plants 1, 2, and 3.

Green EconoME helped a local aerospace identify lighting, HVAC, and thermostat systems that could be upgraded for financial and energy savings. The outdated lighting technology (fluorescent, metal halide, and incandescent) throughout the interior of three plants was replaced with new ballast bypass LEDs. Moreover, intermittently used spaces received occupancy sensors to minimize the burn hours when unoccupied. Total lighting usage for all three plants was reduced by 719,232 kWh, and all three lighting projects had payback periods under 1.6 years.

Energy-efficient lighting solutions are widely commercially available today, and there are many government programs that can help mitigate the replacement or retrofit costs, such as LADWP's Commercial Lighting Incentive Program, which provides rebates on the installation of newly purchased and installed energy-saving lighting and controls.[28] This includes lamp and fixture replacements, as well as sensor-based controls including occupancy and daylight controls. When replacing current lighting, it is important to note that old fixtures like fluorescent lamps should be treated as hazardous waste and should be taken to a disposal center or given to a take-back program.

Conclusion

Manufacturers can take steps to reduce utility costs, improve energy efficiency, and enhance occupant and environmental health by using smart sensors and technologies, transitioning towards electrification, and prioritizing indoor environmental quality. USGBC-LA recognizes that while there isn't a one-size-fits-all approach, the path forward is still clear.

With the rise of research and investment in smart technologies, renewable energy, and battery storage, manufacturers can play a vital role in accelerating industry transformation. Adoption of electric equipment and renewable fuels is one of the best ways to reduce emissions and utility costs. This can be done by replacing individual equipment over time if it is not possible to change the industrial process setup. Another method is partial electrification, which involves the installation of hybrid equipment, and makes electrification more economically viable. In order to reduce rework, it is suggested that digital energy modeling is performed preceding the installation of any conventional, hybrid, or electric equipment.

The last critical component is the interaction between the quality of conditions inside a building and its effects on occupants, also known as indoor environmental quality. When we begin to acknowledge that indoor air quality, thermal conditions, and lighting within a plant significantly affects occupants' health, well-being, and productivity, we can take steps to improve ventilation and filtration, HVAC efficiency and. worker training, and assess lighting quality in relation to plant efficiency and worker health.

The future of smart manufacturing relies on the growth of public-private partnerships, as we've seen in several case studies, including the DOE and CESMII's partnership to develop a unified innovation platform that uses a "concept of profiles," and HyDeal LA and LADWP, where they will service areas of Los Angeles with a combined-cycle gas turbine facility in Utah.

While PPPs remain integral to facilitating growth in the sector, the manufacturing community should work together to achieve three key goals that are critical to the evolution of smart manufacturing: improving the flow of supply chains, workforce education and training, and visual technology integration. Key manufacturers of smart devices and networks, ICT and telecom companies, and providers of operational solutions should work towards developing common standards and protocols.

Manufacturers should report practices, problems, and ideas, to institutes like CESMII so that new enabling technologies are available, along with shared infrastructure capabilities, like the SMIP and profiles. This will foster an open manufacturing platform that is affordable and accessible, benefiting manufacturers and the industry as a whole, and ultimately, bringing us a step closer to mitigating the climate crisis.

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