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Technical Note

Unlocking Energy Efficiency: Debunking Myths on the Road to Decarbonization

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Abstract: Energy efficiency is widely recognized as the foundational and most critical strategy for decarbonizing the manufacturing sector. Misconceptions surrounding energy efficiency measures often hinder their widespread adoption. This article aims to debunk five common myths and provides data and resources to help implement efficiency projects faster and more effectively to achieve greater decarbonization. First, the article challenges the myth that organizations have exhausted all possible energy efficiency opportunities by achieving voluntary energy intensity goals or energy performance certification. Second, it also addresses the misconceptions that efficiency projects are capital-intensive, require many qualified specialists, and have long investment return periods. By presenting real-world case studies and referencing commonly found efficiency opportunities, the article illustrates that energy-savings opportunities are ubiquitous. Organizations can use various contracting mechanisms as well as financial and technical resources from utility companies and government programs to lessen their burden. The notion that efficiency measures can be implemented solely in proprietorship facilities is dispelled. This article emphasizes the importance of green leases and explains that aligning decarbonization goals between the lessor and lessee can help drive savings for both parties. Finally, using unbundled renewable energy certificates as the sole pathway to decarbonization is strongly discouraged. By debunking these prevalent myths, this article aims to foster a deeper understanding of energy efficiency's potential as a cornerstone of decarbonization efforts and to embrace it as a critical pathway toward a sustainable future.

Keywords: energy efficiency; strategic energy management; building sustainability; energy conservation

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1. Introduction

Around the world, there is a frantic effort to reduce greenhouse gas (GHG) emissions by 2050 to keep in line with the Paris Agreement on Climate Change. The agreement calls to keep the global average temperature rise well below 2 °C and to pursue efforts to limit it to 1.5 °C compared with preindustrial levels [1]. Decarbonization can be achieved through multiple pathways deployed across various economic sectors. The US Department of Energy's (DOE's) Industrial Decarbonization Roadmap identified four pillars as main pathways to achieve industrial decarbonization [2]: energy efficiency; industrial electrification; low-carbon fuels, feedstocks, and energy sources; and carbon capture, utilization, and storage. The energy efficiency pillar focuses on lowering energy demand and reducing energy waste, thereby reducing GHG emissions from fossil fuel combustion. Increasing energy efficiency within a facility is foundational and often the lowest-cost approach toward decarbonization. Most often it does not require any major changes to process or system flows and can bring immediate emissions reductions. Energy efficiency also provides nonenergy benefits including lower costs, mitigated risk, and increased competitiveness. Since 2010, the DOE has worked with more than 270 manufacturers to boost efficiency, increase resilience, strengthen economic competitiveness, and reduce carbon footprints via improvements in energy efficiency through the DOE's Better Plants Program. Through this program, the DOE supports 3600 facilities, representing 14% of the US manufacturing footprint, to meet ambitious emissions, energy, waste, and water goals. Collectively, these partners have reported 2.3×10^9 GJ (2.2 Quadrillion Btu) of energy, which equals 131 million metric tons of CO_2 reduction and $10.6 billion in savings [3].

The energy efficiency technologies and management practices available in the market today are widely underused. Combining the effects of energy efficiency opportunities across buildings, industry, transportation, and the electric grid—taking into consideration ambitious but technically possible measures that are likely to be cost-effective—could collectively reduce the expected 2050 US GHG emissions by about half [4]. The pathway for energy efficiency in the manufacturing industry can look very different based on the industrial sector, where manufacturers are in their energy-management and decarbonization journey, and the financial and staffing resources an organization is willing to provide. The pathway can include strategic energy management with the use of energy-management information systems or adopting the ISO 50001 standard [5], performing system-level analysis, or deploying smart manufacturing methods [6]. Strategic energy management fosters an environment that encourages the implementation of energy efficiency and decarbonization technologies and practices. Incorporating efficient systems and machine drives including pumps, fans, and compressors would immediately help cut energy use and emissions.

Organizations can also focus on system-level improvement by evaluating the performance of energy end users such as pump fans and process heating. Process heating (fuel-, steam-, and electricity-based) and machine drives play a dominant role and are responsible for more than 77% of total energy use and 60% of total emissions in the US manufacturing sector [7]. Improper equipment sizing, poor system design, and equipment that is on when not in use all result in inefficiency, increased maintenance, reduced control, and decreased energy performance. These inefficiencies can be countered by using high-efficiency or premium-efficiency motors, installing adjustable speed drives, developing better system designs, properly sizing equipment, and implementing shutdown procedures. In addition, operating drive systems, such as pumps, fans, and compressors, to match end-use requirements helps reduce energy waste. Implementing smart manufacturing (SM) technologies can help energy reduction through improved process control, reduced waste, shorter downtime, and improved performance and productivity [8]. SM requires advanced sensors, monitoring and control systems, and optimization technologies to gather and process data and provide actionable insights to manufacturing personnel. SM can help the manufacturing sector unlock energy-saving potential, which would otherwise be difficult to identify, through practices such as industrial automation.

While the industrial sector has shown progress toward improving energy efficiency, there is always potential to accelerate the adoption of energy efficiency projects. Even with multiple pathways available for driving energy efficiency, many industries do not pursue this path, even if it is economically and environmentally attractive. The major barriers to decarbonization identified by organizations are capital constraints, lack of staffing or technical knowledge, scarcity of opportunities, overreliance on renewable energy certificates, and overinvestments in energy efficiency [9–13]. These myths often lead to underinvestment in energy efficiency, missed opportunities for cost savings and emissions reductions, and an incomplete approach to decarbonization. The focus on these five specific myths in this article is strategic and addresses key barriers to the widespread adoption of energy efficiency measures in the manufacturing sector. By debunking these specific myths with data, case studies, and practical resources, this article aims to empower organizations to take a more comprehensive and effective approach to energy management and decarbonization. Moreover, these myths span various aspects of energy efficiency implementation, from financial considerations to workforce development and leasing practices, providing a holistic view of the challenges and opportunities in this field. Ultimately, by dispelling these key misconceptions, this article seeks to catalyze the more widespread and impactful adoption of energy efficiency measures as a foundational strategy for industrial decarbonization.

By referencing commonly found energy efficiency opportunities in the manufacturing industry, average cost-saving potential, and simple payback, this paper illustrates that these opportunities not only are commonly found but also are easy, “low-hanging” opportunities to provide energy and reduce GHG emissions. Combining energy efficiency efforts with renewable purchases would help an organization achieve deeper energy and carbon savings.

2. Myth 1: My Plant Is ENERGY STAR Certified, or My Company Has Achieved the Energy-Savings Goal with Better Plants, So We Have Done Everything Possible for Energy Efficiency

2.1. The True Meaning of Some Certifications

In 2023, 106 US manufacturing plants earned the US Environmental Protection Agency’s (EPA’s) ENERGY STAR certification [14], which certifies manufacturing plants that are in the top 25% of energy efficiency in their sector. In other words, ENERGY STAR certified plants are more efficient than 75% of their peers (i.e., “similar plants”) for the certified year [15]. However, by definition, the ENERGY STAR certification does not indicate whether a plant has implemented all the feasible energy efficiency projects or even the low- or no-cost energy efficiency projects. In fact, many of the ENERGY STAR certified plants have been implementing energy efficiency projects since receiving their first certificate. For example, Flowers Foods’ Batesville, Arkansas, plant has received the ENERGY STAR certificate six times (every year from 2018 to 2023) [16] while also implementing additional energy efficiency projects annually since 2016. So far, the plant has implemented 13 energy efficiency projects in areas such as the lighting system, compressed air system, pumps, and fans [17].

Since the launch of the DOE’s Better Plants Program, 76 partners have achieved their ambitious, long-term energy-savings goals (i.e., 20% or 25% savings in 10 years). Of those 76 partners, 40 committed to a second goal, and 10 achieved that goal. As of 2022, 7 partners are working on their third energy reduction goal.

2.2. Reasons Why Energy-Savings Opportunities Always Exist

According to Shipley and Elliott, energy-savings opportunities will always exist for multiple reasons, such as the emergence of new technologies, changes in system operators and manufacturing processes, and the increasing unit cost of energy and GHG emissions [18]. The emergence and application of new technologies offer never-before-seen energy-savings opportunities. For example, Lineage Logistics, a Better Plants partner, reduced the blast freeze process time by up to 50% and improved energy efficiency by up to 20% using computational fluid dynamics to optimize the airflow pattern [19]. Lineage also reduced the facility’s energy costs by up to 39% using machine learning algorithms to optimize refrigeration compressor operations [20]. Using advanced mass flow control systems, oxygen sensors in the exhaust stack, and nonlocal decision-making systems, the energy efficiency of process heating systems can be improved significantly compared with the efficiency of mechanical linkage controls [21].

The energy price and/or regulations on carbon emissions make some energy-savings opportunities much more attractive than they were previously. According to the US Energy Information Administration, the electricity price for industrial users increased by 24.7% from 2012 to 2022, going from $0.0667/kWh to $0.0832/kWh [22]. Over the same period, the price of natural gas for industrial users increased by 97.4% from $3.88/Mcf to $7.66/Mcf [23]. In other words, the higher prices of energy reduced the simple payback of energy efficiency projects by 24.7–97.4%, which can help makes some companies’ projects meet payback requirements. In many cases, energy-efficient technology that was once deemed expensive and advanced technology is increasingly common. Technologies now considered standard efficiency practices where applicable include LED lighting, premium efficiency motors, heat recovery systems to capture and reuse waste heat from industrial processes, and variable frequency drives for motors (to control the speed on pumps, fans, and other equipment). Hence, facility managers in charge of implementing energy and emissions reduction projects should stay current with cost trends to estimate the most up-to-date return on investment on their projects.

An improved understanding of manufacturing processes can help to identify new energy-savings opportunities. For example, facilities might have over specified the dryness of compressed air, and they could limit or potentially eliminate the use of desiccant-based dryers (typical energy consumption of 2.0–3.0 kW/100 cfm [24]) and use only refrigerant-based dryers (typical energy consumption of 0.80 kW/100 cfm [24]). Some clean rooms and paint booths might not need as high an air change rate as previously thought. Reducing airflow change rates will result in significant energy savings for heating, cooling, and dehumidification. The same principle goes for the control setpoints for water flow rate, pressure, and temperature. Older facilities often undergo changes to accommodate new production requirements. Specifically, in these cases, extra attention should be given to ensure that old systems are properly decommissioned and that the temperature, pressure, flow rate, and other control setpoints are set to current needs and requirements. Often in these cases, HVAC temperature setpoints, compressed air line pressure, and lighting levels are left unchanged, leading to energy waste.

To maintain savings from energy efficiency opportunities, efficiency measures must be maintained. This requires a robust energy-management practice that prevents inefficiencies from creeping back in. A lighting system with occupancy or motion sensors is the most common measure where controls are overridden by occupants owing to their discomfort. The estimated savings are immediately lost once lighting systems no longer work in the way they are programmed. Another example is a common phenomenon where the room layout is changed so that objects such as cabinets are placed in front of the sensor. Even investment in expensive control technology does not ensure a company will reap the expected savings. In these cases, maintenance or building operators should be notified of the occupancy change or discomfort so they can change the setpoints to ensure that both the occupants are comfortable and that the system is operating as designed. Other energy efficiency opportunities may diminish without a vigorous maintenance routine. These missed opportunities often are small in terms of energy savings but over time can lead to improper equipment sizing, lack of reliable operation, and finally, equipment failure. Compressed air leak maintenance, motor maintenance, and belt replacements are a few examples. Predictive rather than reactive maintenance can eliminate, reduce, automate, or simplify maintenance without compromising reliability or safety and, in many cases, can reduce costs by minimizing downtime [25]. As shown in Figure 1, for facilities without an effective energy-management and maintenance system, the energy consumption and operating costs will continue to cycle and rise if the facilities do not regularly monitor and manage their energy usage [26].

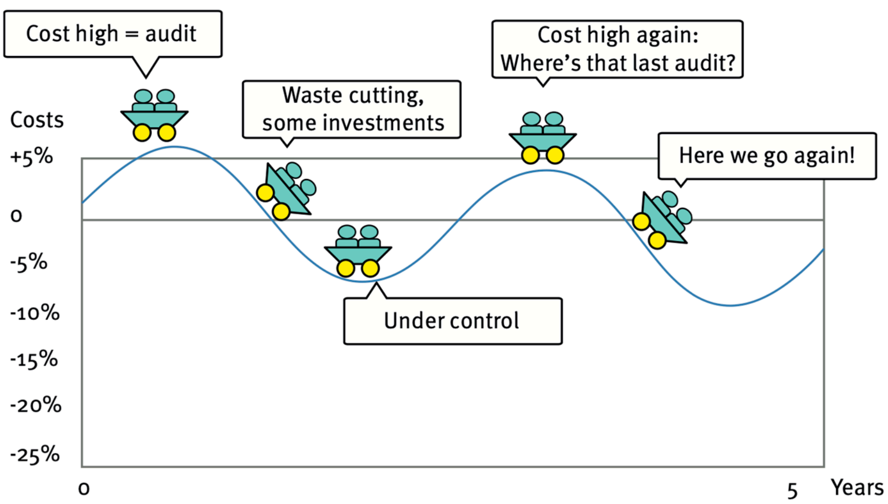

Figure 1. Illustration of the potential results of ad hoc energy management [26].

2.3. Smart Manufacturing Is the New Future of Energy Efficiency

Smart manufacturing technologies offer significant potential for enhancing energy efficiency in the manufacturing sector. By leveraging advanced sensors, real-time monitoring systems, and data analytics, SM enables precise control and optimization of production processes [27]. SM will allow manufacturing companies to create highly efficient, agile data-driven manufacturing processes and IoT integrated systems with sensors and data analytical capability. Intel's IoT projects have helped in predicting pump motor, blower failure, and detecting leaks [28]. This level of control allows for the identification and elimination of energy waste, such as unnecessary equipment operation or inefficient resource utilization. Predictive maintenance capabilities can prevent energy-intensive breakdowns and optimize equipment performance [29]. Additionally, smart manufacturing systems can dynamically adjust energy consumption based on production demands, reducing energy use during low-demand periods. The integration of artificial intelligence and machine learning algorithms can continuously analyze vast amounts of operational data to identify complex patterns and opportunities for energy savings that might be overlooked by human operators [30,31]. Furthermore, these technologies facilitate better energy management across the entire manufacturing facility, from individual machines to plant-wide systems, leading to holistic improvements in energy efficiency. As smart manufacturing evolves, it promises to drive substantial reductions in energy consumption and associated greenhouse gas emissions, contributing significantly to the decarbonization efforts of the manufacturing industry.

3. Myth 2: Most Energy Efficiency Projects Are Capital Intensive and Have a Very Long Payback Period

3.1. Many Energy Efficiency Projects Are Low Cost and Have a Short Payback Period

In 2022, the DOE Industrial Assessment Centers (IACs) performed 568 assessments for small- and medium-size manufacturers and recommended 3692 energy-savings opportunities. Among these recommendations, 1798 recommendations (48.7%) had an implementation cost of less than $5000. More than 1333 recommendations (36.1%) had a payback period of less than 1 year, and 1041 recommendations (57.9%) used fewer than 8 h of labor (or a labor cost of less than $1600) [32].

In-plant trainings (INPLTs) are workshops led by Better Plants Program experts that help train participants on how to identify, implement, and replicate energy-saving projects [33]. Better Plants partners can host an on-site, 3-day training session at one of their facilities and invite others to attend. Technical expertise gained through the INPLTs helps companies overcome common, critical barriers to adopting energy-management practices and technologies. The workshops cover common energy systems such as compressed air, process heating, pumps, fans, and refrigeration systems. Participants can also be trained on energy-management systems such as the DOE's 50001 Ready program or energy treasure hunts to help build a culture of continuous improvement and identify inefficiencies and unnecessary equipment within a facility. From January 2011 to March 2019, the Better Plants Program delivered 123 INPLTs, and the most-recommended opportunities for compressed air, steam, and pump systems are shown in Tables 1–3. The four most-recommended energy-savings opportunities for compressed air systems had an average payback of less than 2.0 years, and three of these recommendations had an average payback of less than 1.0 year. For steam systems, the findings were similar. Five of the seven most-recommended opportunities had an average payback of less than 1.0 year [34]. The tables show that these low- or no-cost opportunities always exist and can come back into operation when organizations do not have strong energy-management programs.

Table 1. Most frequently identified energy conservation opportunities for compressed air systems [34].

Energy Conservation Measure	Average of Simple Payback (Years)
Reduce the pressure of compressed air to the minimum required	0.3
Eliminate leaks in compressed air lines/valves	0.6
Upgrade controls on compressors	0.9
Eliminate or reduce compressed air used for cooling, agitating liquids, moving products, or drying	1.3

Table 2. Top frequently identified energy conservation opportunities for steam systems [34].

Energy Conservation Measure	Average of Simple Payback (Years)
Repair or replace steam traps	0.2
Insulate steam/hot water lines	0.5
Flash condensate to produce lower-pressure steam	0.9
Optimize boiler controls strategy	0.9
Install steam turbine	1.8
Install economizer	2.9

Table 3. Top frequently identified energy conservation opportunities for pump systems [34].

Energy Conservation Measure	Average of Simple Payback (Years)
Remove throttle valves	0.0
Replace existing pumps	2.0
Install variable frequency drive	2.6

3.2. Available Financial Resources from Utility Companies and State and Federal Governments

Many types of financial incentives for energy efficiency projects are available from utility, state, and federal governments, including tax credits, direct funds for project implementations, and loans. Utility energy efficiency programs are designed to meet state energy and GHG emissions reduction goals. The programs provide customers with financial assistance including incentives, grants, and loan programs, whenever available, and with technical assistance such as feasibility studies to reduce expenses and overcome the high up-front costs of installing energy efficiency projects. For example, Flower Foods' Batesville facility partnered with local utility providers to leverage tiered incentives [17]. Over a 5-year period, Flower Foods implemented 13 efficiency projects including steam, compressed air, LED lighting upgrades, waste heat recovery, and variable-frequency drives for exhaust fans. The Batesville facility saved 14,245 GJ (13,506 MMBtu) of energy and received $411,695 in utility incentives, translating to verified utility savings of $231,103 per year. The success inspired Flower Foods to investigate local incentive opportunities for other facilities.

Through the Bipartisan Infrastructure Law, the DOE's Manufacturing Energy Supply Chain office offers IAC implementation grants on a rolling basis. The IAC program provides up to $400 million in implementation grants (up to 50% of the total project cost or $300,000 per manufacturer) funded by the Bipartisan Infrastructure Law to small and medium-sized manufacturers to implement recommendations made in IAC or equivalent assessments [35]. The US Department of the Treasury recently announced the Advanced Energy Project Credit (48C) Program (up to $10 billion) that could help fund more cost-intensive energy efficiency projects [36]. More information on funding and incentives from state and federal government agencies for energy efficiency projects can be found at the Funding and Incentives Resource Hub developed by the Better Buildings Program [37]. This program created Financing Navigator, an online tool to help companies find financing solutions (e.g., energy-as-a-service, energy-savings performance contracts) for energy efficiency projects [38].

4. Myth 3: Energy Efficiency Projects Take Too Much Time and Companies Have No Qualified Staff to Identify and Implement

4.1. Free Technical Resources for Identifying Energy Efficiency Projects

Through the Better Plants Program, partners can receive technical support and many training opportunities at no cost. Partners can apply to host INPLTs for energy treasure hunts or various energy systems (e.g., compressed air, process heating, pumps, fans). INPLT events typically last 3 days and are a combination of energy assessment and workforce development. Host plants receive a detailed list of the identified energy-savings opportunities, including payback, implementation cost, and some needed information for implementation [34]. As of June 2024, Better Plants has delivered 204 INPLTs and identified more than $54 million in energy-savings opportunities while training thousands of individuals and helping with workforce development.

Small and medium-sized manufacturing facilities (fewer than 500 employees at the plant site; annual energy bills of more than $100,000 but less than $2.5 million) can take advantage of the no-cost energy assessments service from IACs based at engineering departments of universities [39]. The IAC energy assessments typically are 1- or 2-day visits, and the IAC team performs detailed measurements and analyses to identify savings opportunities. The team provides an energy assessment report with detailed recommendations within 8–12 weeks after every assessment. Since the launch of the IAC in the early 1980s, IACs have performed more than 21,350 energy assessments with more than 159,083 energy-savings opportunities [32]. Many utility companies also provide free energy assessments, especially for industrial energy users; information can be found on their website or by talking to their representatives. Finally, many engineering consulting firms provide energy assessment services without the need for much technical support from the facilities.

4.2. Solution to Lack of Qualified Staff

Driving energy efficiency can be achieved by engaging employees with all levels of technical skills within an organization as long as they are empowered and incentivized. They can tap into their operational knowledge and promote a culture of continuous improvement. As part of the annual ArcelorMittal's Energy Fair, the company launched the Power of 1 contest to encourage individual employees and teams to submit low- and no-cost energy-savings project ideas for their facilities [40]. The winning ideas will save the company on energy costs and provide an opportunity for employee recognition. Over 3 years, ArcelorMittal has implemented 15 projects from the contest, resulting in total savings of approximately $500,000 from low- and no-cost solutions offering short payback periods and high cost-effectiveness.

The DOE has many free workforce development programs to equip manufacturing workers with the skills to identify and implement energy efficiency projects, including INPLTs, virtual training, and energy and decarbonization bootcamps [41]. These workforce development programs have trained more than 4800 people and covered more than 15 topics, including all major manufacturing energy systems, water efficiency, renewable energy, and other pillar technologies for decarbonization. Better Plants partner OxyChem hosted a 3-day INPLT focused on the plant's steam systems efficiency improvement opportunities across the chlor-alkali production process at their Ingleside facility. OxyChem trained newly hired engineers and interns using the materials from the steam INPLT as part of their onboarding process and incorporated the material into corporate learning modules as part of their engineering training and development program for technical engineers. The Ingleside facility has identified and implemented multiple opportunities during the

INPLTs that have helped reduce the plant's energy usage by 139,267 GJ (132,000 MMBtu) of natural gas and reduced their GHG emissions by 7000 metric tons of CO_2 equivalent annually [42]. Tyson Foods hosted two INPLT energy treasure hunts at their facilities in Rogers, Arkansas, and Carthage, Mississippi. The energy treasure hunt project directly resulted in over 3,312,081 kWh in annual energy cost savings, with more than 15% of energy-savings potential associated with industrial refrigeration systems [43]. The success of these treasure hunts led the Tyson Foods team to investigate deeper energy savings from refrigeration-related improvements and other energy-intensive areas of improvement.

Information and knowledge of energy equipment and systems (e.g., steam traps, pumps, fans) in their own facilities can increase employees' engagement and commitment to energy reduction, which leads to more effective participation from employees. Easily accessible information on the amount of money and energy wasted through inefficiency can also motivate employees to identify energy-savings opportunities. Celanese Corporation created "Energy Sparks", which are "did you know" conversation starters and fact sheets on energy topics relevant to manufacturing facilities [44]. These helped Celanese to communicate in a simple format to stimulate conversation, initiate action at the shift team level, and ultimately change occupant behavior. Similarly, 3M developed "Energy Manual 81" to provide their employees with detailed energy-saving considerations for system design and procurement. This manual focuses on systems and operations that are most common in 3M facilities. With the help of subject matter experts and the corporate energy team, the guidelines laid out are in line with ASHRAE standards; environment, health, and safety requirements; and 3M quality standards. This manual incorporates energy-efficient design into every project, specifies operating conditions for primary and auxiliary equipment, and outlines metering specifications based on energy consumption thresholds. Employees are required to refer to Manual 81 for any engineering project that has a capital cost greater than $250,000. Since the launch of Manual 81, implemented projects have delivered 7,043,552 GJ (6,676,000 MMBtu) of savings and 272,000 tons of CO_2 equivalent savings with a payback period of 2 years [45].

Efficiency-as-a-service (EaaS) is a results-based financing model that eliminates the need for upfront investment and qualified staff for energy-efficient projects [38]. Instead of paying for equipment and managing the project implementation, facilities pay for cost via the actual savings achieved and do not get involved in the project implementation. EaaS providers cover all project costs, including design, implementation, and ongoing maintenance. This financing model can help address not only the need for financial resources but also the need for qualified staff for project implementation and maintenance. For example, Bentley Mills worked with Redaptive and PricewaterhouseCoopers to prepare a master agreement and audit the project [46]. Two projects were identified for the plan—an LED retrofit for the entire facility and the installation of high-efficiency fixtures for all domestic water use at the facility. As part of the agreement, Redaptive provided a warranty stating that if any lamps of the new lighting system underperformed, they agreed to repair the underperforming units within 90 days. Once the savings were achieved, ownership of equipment reverted to Bentley Mills. Annual energy savings from the lighting retrofit are estimated to be 1.3 million kWh, with the system outperforming this estimate by 10% in the first 3 months. General Motors (GM) also has executed an energy performance contracting model, with projects totaling more than $40 million in investment [47]. Projects implemented in the first 2 years included lighting retrofits and controls—T8, LED, outdoor lighting, and wireless controls for facilities. GM also added a steam elimination project at a stamping plant where building heating is not closely affected by production.

5. Myth 4: We Are in Leased Space and Have Little Control over the Building Operation

5.1. Negotiate a Better Lease

One of the major obstacles to reducing energy consumption in a leased space is the structure of a standard lease. Traditionally, the owners were responsible for energy-efficient operation of a leased space because they had more operational control over building systems. However, tenants play a critical role in achieving lasting energy reduction. The owner might have control over mechanical systems such as central heating, fans, cooling towers, and lights, but the tenant has control over the thermostat to control the temperature in the space, control plug loads, and turn lights on and off. Hence, both parties are responsible for managing the energy consumed in a leased space. Based on the leased structure, either the lessor or the lessee might have more control, but both parties need to collaborate to realize energy efficiency savings. Green leasing practice allows tenants and landlords to collaborate and save energy, reduce operational costs, and achieve organization-wide sustainability goals.

Tenant spaces are often developed in a "built to suit" or speculative way. Buildings that are built to suit are designed for a particular occupant and are ready for the occupant once construction is complete. Speculative buildings are often built in stages because the occupants are not usually known at the time of design. For speculative buildings, the developer constructs the foundation, structure, building envelope, and electrical and mechanical systems. The tenant then pays to build out the space to meet their needs. The major drawback of this type of construction is the designer of the project makes assumptions about the occupant's needs to complete the electrical, mechanical, and plumbing design. The designer has no information on the ventilation requirements, occupant density, schedule, or indoor temperature requirements. To reduce costs, energy-efficient equipment is often overlooked in favor of cheaper systems.

The Tenant Energy Analysis and Metric Program managed by the Urban Land Institute helps to deliver a 10-step replicable process to integrate energy efficiency into tenant space design and construction [48]. Better Plants partner Estee Lauder Companies, a leading manufacturer and marketer of cosmetics, has a 929 m^2 (10,000 ft^2) office space in Manhattan, New York. Estée Lauder decided to follow the tenant energy optimization process to design and construct its new space. The team outlined energy performance goals aligned with Estée Lauder's overall corporate sustainability targets and developed an extensive list of energy performance measures aimed at reducing energy consumption to be considered for implementation in the final build. The measures considered included high-efficiency lighting (7.5–9.7 W/m^2 or 0.7–0.9 W/ft^2), lighting shutdown based on zone occupancy sensors, daylight harvesting, master shutoff switch, and ENERGY STAR rated equipment (4.3 W/m^2 or 0.4 W/ft^2) [48]. Throughout a 6-year lease, these measures were estimated to reduce electricity use by 12.1% and save more than $15,000 in electricity costs with an ROI of 42% and a payback period of 3.7 years. These energy efficiency measures totaled $13.8/$m^2$ ($1.29/$ft^2$) in incremental implementation cost.

5.2. Opportunities in Rented Spaces

Green Lease Leaders was created by the Institute for Market Transformation and the DOE Better Buildings Alliance to recognize landlords and tenants who have implemented energy efficiency in a portfolio of leased spaces. This program helps set the standard for green leases. There are three levels of green lease. *Silver* recognizes companies that have incorporated green leasing into their standard lease form, *Gold* recognizes companies that have executed a green lease, and *Platinum* recognizes companies that are integrating building performance with inclusive, equitable outcomes and financial and sustainability improvements. The Green Lease for Leaders Reference Guide for Tenants provides details on the requirements for each level to qualify for recognition. At a minimum, tenants at all levels must provide sustainability contact to landlords and require minimum efficiency standards for leased space fit outs. Table 4 shows some of the best practices a tenant can request to include in a standard lease form, corporate policies, or other documentation.

Table 4. Green lease leader prerequisites and credits [49].

Best Practices in a Standard Lease Form, Corporate Policies, or Other Documentations
1. Track energy use across leased spaces
2. Track water use across leased spaces
3. Request energy performance score from landlord annually
4. Ensure the transaction management team receives energy training
5. Implement tenant energy-management best practices
6. Purchase renewables if offered by landlord and competitively priced
7. Accept cost recovery for efficiency upgrades benefiting tenant
8. Include environmental social governance requests in the site selection questionnaire
9. Commit to actively contributing to a whole building performance reduction goal in carbon or energy use intensity
10. Establish social impact goals for health, wellness, diversity, and inclusion
11. Establish impact goals for building resilience and climate risk

Ultimately, what type of lease is negotiated and what energy efficiency features are installed depends on the negotiating leverage. In a low-vacancy, owner-friendly market, building owners may provide minimum to no tenant improvement allowances. The owners might even charge a premium for the upgrades. Furthermore, brokers who help with negotiation are motivated by commissions and often leave out energy efficiency topics in negotiations for a quick and simple deal closure and may try to eliminate complicated negotiations. Similarly, owners in a competitive market may suspend complex negotiations involving energy efficiency and lean toward tenants with simpler demands. A vast number of tenants remain unaware of the financial benefits of energy efficiency in leased space. The tenant's primary focuses when trying to find a new space for lease are location, rent, space suitability, and amenities. Energy efficiency is a distant fifth—or lower—on the list of priorities because energy cost might be \$22–\$43/m^2 (\$2–\$4/ft^2), compared with rent that can range from \$828/m^2 (\$77/ft^2) in Manhattan to \$463/m^2 (\$43/ft^2) in Austin, Texas, to \$16/ft^2 in Tulsa, Oklahoma. Because brokers hold the key to what gets negotiated as part of the lease, they play a critical role in interpreting, explaining, and advising their clients on the lease terms. The landlord's willingness to include energy efficiency measures also depends on the length of the lease. If tenants will occupy a space for only a few years, landlords are hesitant to invest in a building system that lasts beyond that time because it might not be applicable or attractive to the next tenant.

Tenants often are unsure of what energy efficiency upgrades to request, and landlords are unsure what the return on investments would be for some of these projects. Split incentives are one the most cited barriers in a leased space. It can be difficult to decide who accrues the costs and benefits of energy efficiency measures. In a typical scenario, capital costs may be the responsibility of the owner, but operational costs are borne by the tenant. For example, if a building owner invests in more efficient lighting technology, the financial benefits of reduced energy consumption will flow partially or entirely to the tenant, depending on the lease structure. However, if energy is included in the lease, the tenant does not benefit from the energy reduction. Owners may have the right to pass through the costs of upgrades to the building tenant, often referred to as a cost recovery clause, if that investment will lead to a financial benefit to the tenant. In such cases, both the tenant and the landlord should know the expected savings from some common energy efficiency measures. Table 5 provides a list of measures with typical energy reduction potential [50].

Table 5. Typical energy reduction potential of various energy efficiency measures [50].

Energy Efficiency Measure	% Energy Reduction	Cost
High-efficiency lighting	30–60%	\$54/m^2 (\$5/ft^2)
Lighting control technologies	24–38%	\$22/m^2(\$2/ft^2)
Daylighting	20–80%	≤\$54/m^2 (\$5/ft^2)
ENERGY STAR Certified appliances and office equipment	10–40%	\$538–\$2152/m^2 (\$50–\$200/ft^2)
Plug and process load inventory and reduction strategies	20–50%	Based on equipment
High-efficiency HVAC units for above-standard operations	5–20%	\$100–\$180/ton
Point-of-use domestic water heating	27–50%	Based on equipment
Energy-management and information systems	10–15%	\$3.2–\$11.4/m^2 (\$0.30–\$1.06/ft^2) *
Optimization of outside air volumes according to tenant occupancy	Varies based on building occupancy	\$0.54–\$10.8/m^2 (\$0.05–\$1/ft^2)
Data centers and IT server room best practices	80%	\$276,000–\$770,000
Improving building envelope performance	Varies based on building age	NA
HVAC zoning	Depends on current controls	\$32–\$65/m^2 (\$3–\$6/ft^2)
Window attachments	5–17%	≤\$21/m^2 (\$2/ft^2)
Utility metering and submetering	NA	\$700–\$5000

* Depending on the age of the building and other factors.

6. Myth 5: Unbundled RECs Are More Attractive Compared with Energy Efficiency Measures

6.1. Prioritize Energy Efficiency over Unbundled REC Purchases

Organizations with an emissions reduction goal are purchasing renewable energy as a way to reduce their greenhouse gas emissions. Depending on the industry, Scope 1 emissions as a result of burning fossil fuel on site are often the largest portion of GHG emissions but also one of the hardest to mitigate. On the other hand, electricity accounts for the majority of Scope 2 emissions for all companies and is much easier to mitigate through the purchase of renewable electricity. In 2022, 9.6 million customers purchased 272 million MWh of renewable energy in addition to energy consumption through their load-serving entities [50]. The purchase of unbundled RECs still dominates the market, though power purchase agreements and community choice aggregation are slowly gaining momentum. Any investment toward bundled or unbundled RECs encourages more renewable electricity on the grid and should never be discouraged. Energy efficiency is the most cost-effective way to reduce emissions but is often overlooked in the world of decarbonization. It helps to reduce operational costs and reduce energy demand, which further helps in increasing energy security and reliability in the supply chain. By embracing energy efficiency practices, individuals, businesses, and society as a whole can reap significant economic, environmental, and social benefits.

The purchase of unbundled RECs does not mean an organization is purchasing physical electricity but rather is purchasing energy certificates. This allows the renewable energy generator to sell the electricity to the grid and sell the certificates to other buyers.

These buyers can then claim they purchased clean power. This transaction does not ensure displacement of the fossil fuel-powered electricity generators and does very little to decarbonize the grid. If the electricity demand of the consumer increases, the utility is compelled to bring more fossil-powered peak load units online, resulting in even higher GHG emissions. Each MWh of RECs helps reduce emissions from 1 MWh of electricity. However, each MWh of electricity may have a different carbon footprint depending on the fuel mix and time of day. In 2022, 110 million MWh of unbundled RECs was generated [51]. Energy efficiency measures result in a direct reduction in consumption and also help to reduce peak demand. As long as the energy efficiency measure is maintained, the company will not have to pay for that amount of energy. Because an REC is an absence of consumption, people often do not realize the reduction they have achieved by implementing that measure, and it is often overlooked.

States in the US are divided into voluntary and compliance markets. Depending on the state in which a customer is located, the price of RECs may vary. In the compliance market, utilities are required to provide a certain percentage of electricity through renewable energy known as the Renewable Portfolio Standard. Utilities purchase large amounts of unbundled RECs, which then increases the cost of RECs. The estimated average cost for compliance RECs in 2021 was $33.94 per credit, compared with $3.00 per credit for voluntary RECs [52]. For example, RECs in PJM Interconnection LLC cost about $32.22 owing to the Renewable Portfolio Standard compliance markets in Delaware, Maryland, New Jersey, Ohio, Pennsylvania, and Virginia. The REC cost in the Midwest Renewable Energy Tracking System is estimated at around $45.18. REC prices in all regions in the US are projected to rise, so companies purchasing RECs to reduce their GHG emissions are likely to pay increasingly higher prices to meet their decarbonization goals.

6.2. Combine Energy Efficiency with Renewable Energy Purchase for Higher Emissions Reduction Impact

Financing approval for sustainability projects requires the project to meet the minimum return on investment (ROI). ROI is a popular profitability metric used to evaluate investments and compare different investments. Energy projects are designed to reduce energy consumption and lower energy costs, which result in cost savings. A project's ROI involves estimating the cost of implementation and expected savings over a certain period. A high ROI indicates energy efficiency projects are a good investment and will provide significant savings over time. Financing such as utility incentives, rebates, and external funding sources can help with reducing ROI by reducing the cost of upfront investment. The purchase of RECs does not offer a traditional ROI because energy consumption is not reduced. Organizations purchasing RECs would have to continue purchasing them annually to help reduce their Scope 2 emissions. Although RECs help in reducing emissions, they do not have a profitability metric for comparison. Owing to the increase in the price of RECs, organizations most likely will continue to pay high premiums to get higher quality RECs from the power market.

Decarbonization initiatives by organizations have brought about other unique financing mechanisms such as internal carbon pricing, also known as the internal cost of carbon or shadow pricing. By setting a price on carbon emissions, organizations can better manage climate risk and evaluate business strategies that prepare them for a low-carbon future. The internal cost of carbon also makes decarbonization projects more attractive by lowering the ROI and encouraging projects with higher GHG emission effects. When using an internal cost of carbon, RECs with energy efficiency projects now have an ROI and can be compared based on which method offers the higher emission reduction. Even in this case, energy efficiency projects ensure a reduction in peak demand and would require organizations to purchase fewer RECs. To achieve greater decarbonization, organizations should leverage both energy efficiency and renewable energy purchases to increase their GHG emission reduction potential.

7. Conclusions

Energy efficiency remains a critical and often underutilized pathway for industrial decarbonization. This paper has addressed several common myths that may deter organizations from fully embracing energy efficiency measures. We have demonstrated that energy-saving opportunities are continually present, even in facilities that have already implemented efficiency programs or achieved certifications. Many energy efficiency projects are low-cost with short payback periods, and numerous financial resources are available to support implementation.

Furthermore, we have shown that a lack of qualified staff need not be a barrier, as there are many free technical resources and workforce development programs available. Workforce development plays a pivotal role in a company's decarbonization efforts by equipping employees with the necessary skills, knowledge, and mindset to identify, implement, and maintain energy-efficient practices and technologies. By investing in training programs, energy treasure hunts, and continuous education, companies can create a culture of sustainability that empowers employees at all levels to contribute to emissions reduction goals, ultimately driving long-term success in decarbonization initiatives and fostering innovation in clean energy solutions.

Finally, combining renewable energy adoption with energy efficiency measures creates a synergistic approach that maximizes the benefits of decarbonization efforts. While renewable energy sources reduce the carbon intensity of electricity consumption, energy efficiency measures decrease overall energy demand, allowing renewable sources to meet a larger proportion of a company's energy needs and potentially reducing the size and cost of renewable energy systems required. This integrated strategy not only accelerates emissions reductions but also optimizes resource utilization, enhances cost-effectiveness, and improves the resilience of a company's energy infrastructure in the transition to a low-carbon future.

The path forward for industrial decarbonization should involve a comprehensive approach that combines robust energy-management practices, the continuous identification and implementation of efficiency opportunities, and the strategic use of renewable or low-carbon energy, electrification, and carbon capture. By dispelling these myths and embracing energy efficiency as a foundational strategy, industries can achieve significant reductions in energy consumption and greenhouse gas emissions while improving their economic competitiveness and resilience. As the urgency of climate action grows, it is imperative that industries fully leverage the power of energy efficiency alongside other decarbonization strategies. This multi-faceted approach will be crucial in meeting ambitious emissions reduction targets and transitioning to a low-carbon future.

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