ADVANCING SUSTAINABILITY IN C&Q PROJECTS:

From Inception to Eco-Efficient Implementation

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Sustainability principles can be effectively integrated into commissioning and qualification (C&Q) projects to support environmental goals without compromising compliance, quality, or patient safety. By positioning C&Q as both a verification tool and an enabler of sustainable intent, this article outlines a practical path for the pharmaceutical sector to enhance operational efficiency, reduce environmental impact, and support eco-conscious future.

INTEGRATING SUSTAINABILITY INTO PHARMACEUTICAL PROJECTS

In recent years, sustainability has become a widely discussed topic and a top priority across various industries, including the pharmaceutical sector. The pharmaceutical industry is distinguished by its stringent regulatory requirements and complex manufacturing processes. With the increasing demand for environmental responsibility, the industry has been shifting toward integrating sustainability practices in various facets of its operations. One significant area where sustainability can be effectively implemented and measured is in the C&Q stage, which is vital for ensuring that facilities, equipment, and processes adhere to regulatory standards, operate effectively, and do so without compromising compliance, quality, or patient safety. This crucial phase should be viewed not only as a time for rigorous testing and documentation to ensure that systems function reliably and consistently, but also as an opportunity to seamlessly integrate and verify sustainability initiatives.

As sustainability becomes a key business requirement, integrating ecofriendly practices in C&Q projects is essential to meet today's needs without compromising future resources. This article explores the opportunities and strategies for embedding sustainable practices [1] into a C&Q framework to help the industry transition toward a greener, more efficient future. Incorporating sustainability into C&Q processes is not only about reducing environmental impact; it also offers tangible business benefits, including improved operational efficiency, cost savings, and alignment with global environmental goals. Emphasizing the role of Good Engineering Practices (GEP) and sustainability by design (SbD), the article presents a structured, life-cycle-based approach to embed eco-efficient practices from project inception through implementation.

The opportunities vary depending on the stage within the project life cycle. Each stage should be evaluated for its contribution to the sustainability of the equipment and facility, and for potential reductions in both consumption and waste [1]. By adopting sustainable approaches, organizations can reduce energy consumption, minimize waste, and optimize resource utilization. These practices contribute to the industry's transition toward a greener future while maintaining the high standards required for product quality and patient safety [1].

This article focuses on exploring opportunities and sharing the thought process on how sustainability principles can be integrated into pharmaceutical C&Q projects through GEP, with C&Q serving as a verification mechanism for the sustainable design intent. It does not delve into the technicalities of the C&Q approach or process or its deliverables, as these processes are well established and covered extensively the ISPE *Baseline® Guide Vol. 5: Commissioning & Qualification* (2nd Edition) [2].

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THE EVOLUTION OF SUSTAINABILITY

The concept of sustainability has significantly evolved since the 1972 United Nations Conference on the Environment in Stockholm, with the Brundtland Commission later defining sustainability as "Meeting the needs of the present without compromising the ability of future generations to meet their own needs" [3]. Sustainability has emerged as a priority since then across various industries, including the pharmaceutical sector, where efforts are increasingly focused on innovating and developing sustainable solutions, integrating environment friendly practices into all aspects of operations. As environmental concerns grow, organizations are increasingly focusing on incorporating sustainable practices into all aspects of their operations to drive positive change and long-term benefits [4]. This shift toward sustainable practices extends beyond regulatory compliance and corporate social responsibility, aiming to optimize resource usage, minimize environmental impact, and enhance operational efficiency.

A TOP-DOWN APPROACH TO SUSTAINABILITY IN AN ORGANIZATION

To create a meaningful impact, sustainability initiatives and practices should start from the senior management in an organization [1]. Integrating sustainability into a company's value, culture, and everyday practices not only benefits the environment but also enhances efficiency and improves economic and social welfare. Senior management is key to embedding sustainability into core values, ensuring all employees align with the goal of reducing environmental impact.

Embedding sustainability as a core aspect in an organization requires defining a clear sustainability goals and implementing concrete actions. This involves establishing measurable sustainability targets, key performance indicators (KPIs) and sustainability reporting that allow organizations to track its progress and assess its impact [1, 5]. Furthermore, it requires integrating sustainability into the organization's decision-making processes, and operational strategies. By fostering a commitment to sustainability at all levels, organizations can ensure that their initiatives are not only impactful but also aligned with their long-term vision and values [4]. These efforts contribute to transform the industry toward a more sustainable future across the value chain [5].

SUSTAINABILITY: INCEPTION THROUGH DESIGN

Creating a sustainable framework involves critical thinking and designing systems and processes that prioritize long-term environmental, economic, and social well-being. A holistic approach is essential, combining resource efficiency, renewable energy, waste reduction, and economic viability to drive innovation and improvement [1, 5]. A good design can help reduce waste, save energy, conserve natural resources and create long-lasting, environmentally friendly solutions. The key is to set clear expectations and communicate sustainability requirements to relevant stakeholders, aligning them for developing ecofriendly solutions and support "built-in" sustainability [6]. This can be achieved by embedding sustainability in design [4, 6].

SbD is a framework that integrates sustainable principles into the design and development process from the inception, aiming to create products, services, or systems that minimize negative environmental impacts and maximize positive outcomes throughout their life cycle [4]. This framework encourages an early engagement and harmonization among all stakeholders in establishing formalized project needs and performance targets [5]. By applying these requirements early on, organizations can ensure that sustainability is incorporated from the design phase, leading to systems that are more efficient and aligned with long-term environmental goals [4, 6].

SbD emphasizes life cycle thinking, resource efficiency, and circular economy practices by designing for reuse, recycling, and reduced waste [4]. The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended [7]. This approach goes beyond environmental considerations to include social and economic factors, ensuring that solutions are equitable and economically viable. By embedding sustainability into the early planning stages, companies can optimize resource utilization, achieve regulatory compliance, and enhance brand reputation.

Figure 1 emphasizes that the early stages of a project present a greater opportunity to influence sustainability while keeping the costs low. As the project advances, costs steadily increase, while the ability to make impactful sustainability decisions diminishes. Late-stage interventions not only become more expensive but also prove less effective. This highlights the importance of prioritizing sustainability considerations early in the project life cycle to maximize influence and minimize costs.

Figure 1: Sustainability curve.

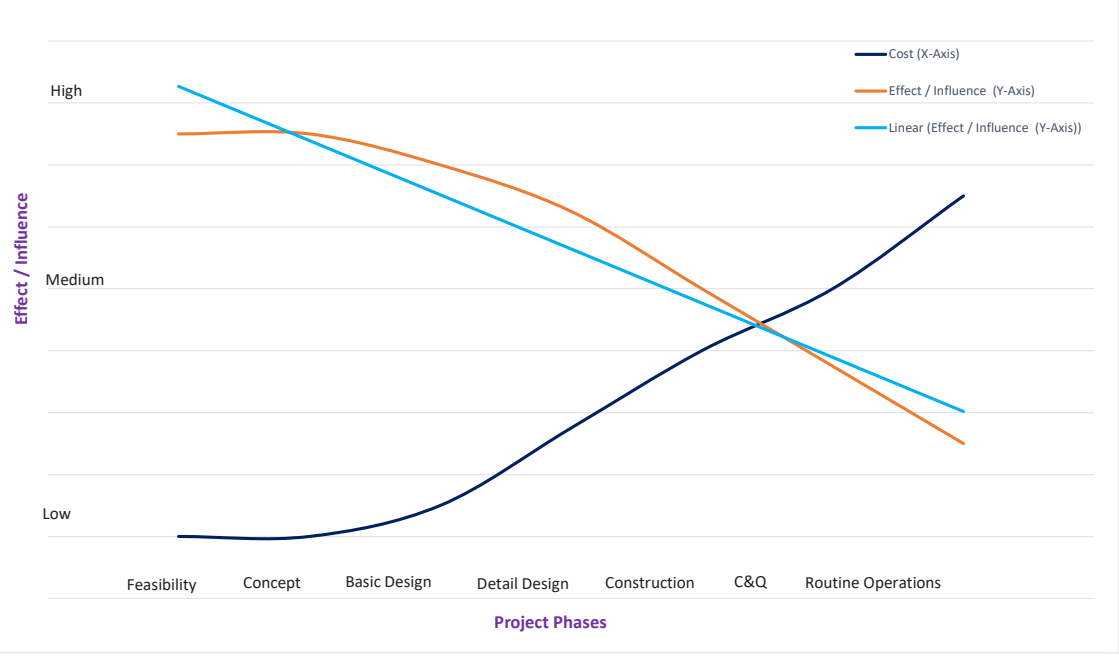
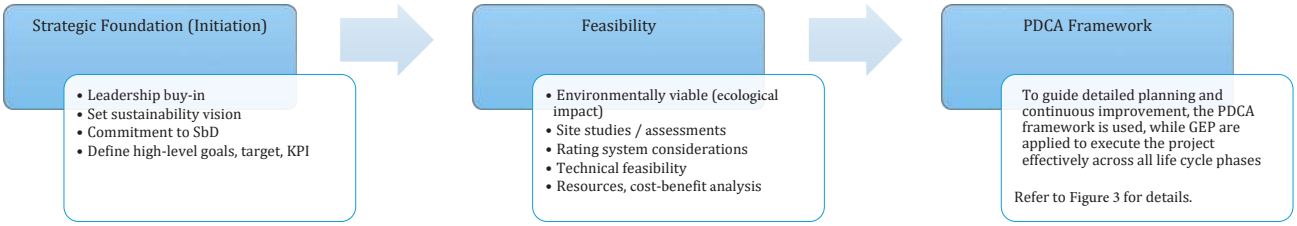


Figure 2: Example sustainability implementation flow.



HOW C&Q ENABLES AND VERIFIES SUSTAINABILITY

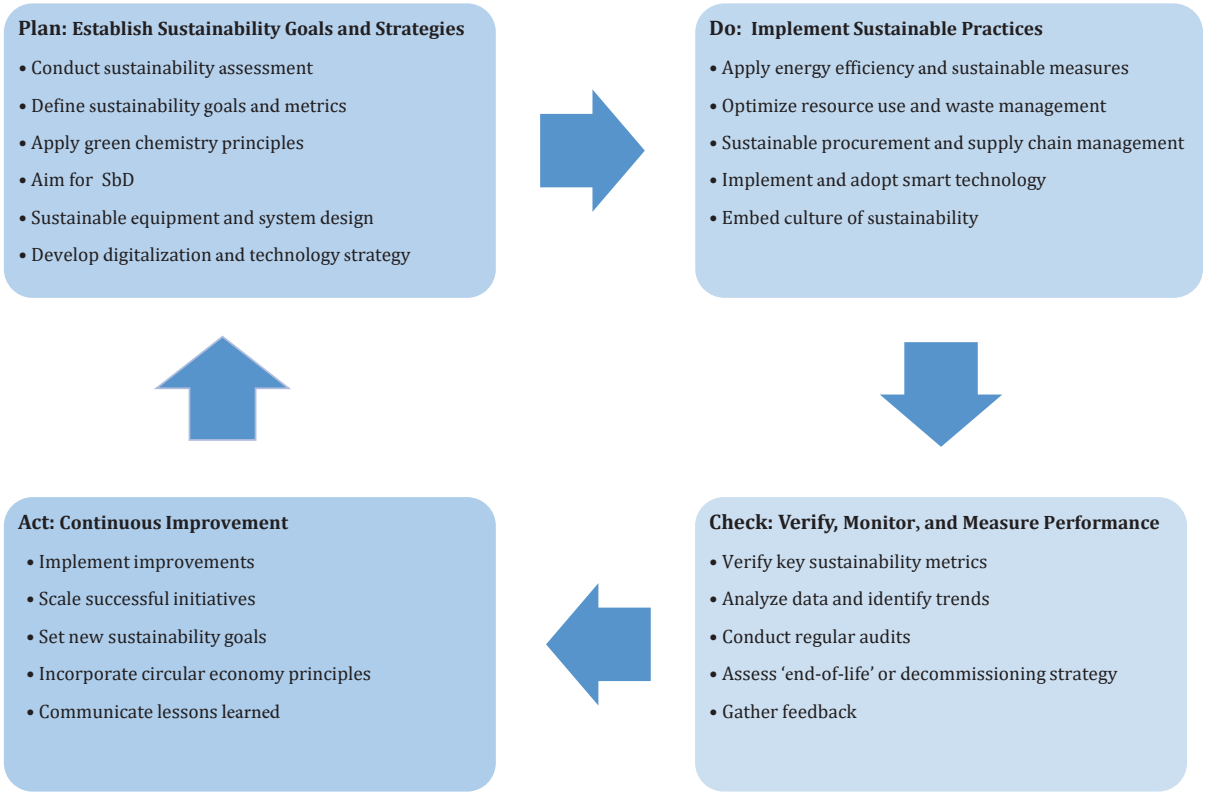
Building sustainability from inception is essential, but it's through execution that these goals are realized and verified. Hence, it is important to understand and distinguish between where sustainability should be driven and where it can be verified. Sustainability should be driven during initial planning and design phases. Sustainability can be verified through GEP-driven execution during commissioning and actual operations by periodic verification and/or monitoring to ensure that sustainability requirements are fulfilled.

Sustainability is not currently a regulatory requirement and doesn't come under Good Manufacturing Practice (GMP) frameworks (e.g., 21 CFR Parts or EU GMP Annex 15) [8, 9]. Instead, it is best handled through GEP. Commissioning is the primary sustainability enabler; it ensures sustainability features work as designed. Qualification, though primarily focused on verifying systems for product quality and patient safety, may also include sustainability features when they impact critical design elements or control strategies. For example, an energy-efficient system such as a solar-powered cold chain refrigeration system that influences a temperature control is relevant to both sustainability and product quality. In such cases, these features must be verified as part of the qualification process because they impact product quality.

BUILDING A SUSTAINABLE C&Q FRAMEWORK

C&Q planning begins early in the project, so it is essential to initiate sustainability measures from the start by embedding SbD principles during the initial design, as shown in Figure 2. This ensures sustainability values are integrated into the process, facility, and equipment design from the beginning and serve as a

Figure 3: Sustainability approach using the PDCA cycle.



central focus throughout the life cycle of a pharmaceutical facility rather than an afterthought [1]. Early planning lays the foundation for careful design and decision-making, thereby significantly reducing environmental impacts and operational costs over time. To achieve this, it is essential to involve a sustainability expert and other experts from cross functions like manufacturing, engineering, vendors, C&Q, and quality assurance from the initial stage of the project. Involving sustainability experts at every stage ensures that sustainable practices are seamlessly integrated into every aspect of the project life cycle.

Creating a sustainable framework requires a structured, adaptable, and efficient approach that ensures quality, safety, and compliance across equipment, facilities, and processes while aligning with regulatory standards and fostering continuous improvement. The Plan-Do-Check-Act (PDCA) cycle is key here, offering an iterative model that drives sustainability goals at each phase [1]. A PDCA framework can help drive measurable sustainability outcomes across facility design, procurement, commissioning, and operational phases. The PDCA cycle makes sustainability a dynamic, measurable commitment throughout the manufacturing life cycle, rather than a one-time consideration. Figure 3 shows a PDCA cycle with key activities for a comprehensive, sustainable approach.

To adopt the framework, begin with a feasibility study (as shown in Figure 2) that evaluates sites based on ecological impact, cost-benefit considerations, and resource use. Prioritize locations where sustainability improvements are most needed and explore opportunities to improve them. Setting energy efficiency targets early can guide decisions on sustainable facilities, renewable energy integration, and efficient systems. Rating systems like Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) can be adopted to measure environmentally sustainable facilities [1]. Conducting a life cycle cost analysis helps identify the technical and economic feasibility of long-term investments in sustainable materials, equipment, and facilities [1]. These are foundational for planning a project that prioritizes both environmental and operational efficiency, ensuring long-term viability and sustainability.

Step 1. Plan: Establish Sustainability Goals and Strategies

During the planning phase, identify and establish sustainability objectives, strategies aligning with the organizational values, industry standards, and regulatory requirements. Include sustainability criteria in the planning documents and project charters.

An integrated C&Q process—based on a science- and risk-based approach as per ISPE [2]—can be adopted to reduce the number of tests and to leverage earlier stages of testing into later stages [1]. By focusing on high-risk areas, companies can reduce resource consumption and minimize waste generation on redundant testing during qualification. With proper planning and consideration, activities like resource allocation, budgeting, list of deliverables, and timeline planning are aligned with sustainability goals. This early focus guides decisions throughout the project, promoting environmentally friendly choices in design, procurement, installation, and C&Q activities.

Conduct sustainability assessment

Assess the environmental and economic impact of current operations to establish a clear baseline for improvement [1]. This evaluation should encompass greenhouse gas emissions, energy and water usage, resource consumption, and waste generation. Use reliable data sources to ensure accuracy, identify critical areas for enhancement, and ensure alignment with relevant local and global sustainability standards. The assessment should produce detailed, measurable, and actionable results, providing a foundation for implementing sustainability initiatives and tracking progress. Where feasible, incorporate mitigation strategies into the design; otherwise, address them through procedural controls.

Define sustainability goals and metrics

Establish clear sustainability objectives along with specific metrics to track progress. This may include reducing emissions; conserving water, paper, and energy; and minimizing waste. Goals should be SMART (Specific, Measurable, Achievable, Relevant, Time-bound) to facilitate clear tracking and accountability. Develop KPIs for each goal to quantitatively measure progress for meaningful sustainability improvements and transparent reporting.

Embed these sustainability requirements within the user requirements specification (URS) document, as this is the primary reference document throughout the life cycle of the facility, equipment, or system. Setting clear sustainability goals and documenting as URS fosters collaboration, accountability, and traceability throughout the system life cycle [1]. This ensures sustainable practices are integrated at every phase, supporting compliance and long-term environmental goals.

Apply green chemistry

Green chemistry is a field dedicated to creating processes and products that minimize or eliminate hazardous substances. Its goal is to design chemical processes that are environmentally responsible, economically sustainable, and safe for human health [1]. Integrating green chemistry principles [1] into process development and manufacturing prioritizes the use of safer, renewable materials, reducing the environmental footprint and safeguarding human health from harmful substances [4].

By emphasizing innovation and sustainable practices, products can be designed to be safer, more efficient, and environment friendly while aligning with regulatory requirements. This includes the use of biodegradable and low-toxicity cleaning agents for cleaning cycle development that are effective at lower concentrations, reducing the chemical load on systems.

Aim for SbD

Integrating sustainability into the design phase of equipment, processes, and infrastructure involves selecting ecofriendly materials, energy-efficient technologies, and waste-reduction strategies from the outset. When designing a facility, integrating building information modeling (BIM) with environmental review tools—such as like life cycle assessment (LCA), energy modeling, and carbon footprint tools— ensures sustainability is embedded in the design review process and opportunities are effectively utilized [1]. The goal is to minimize environmental impact, conserve resources, and enhance the longevity of the product or system.

By prioritizing renewable materials, efficient energy use, and resource conservation, designs can create lasting value while reducing waste. Additionally, designing and optimizing processes such as cleaning cycles in clean-in-place (CIP) systems, parts washers, and garment washers helps minimize water and detergent usage, contributing to sustainability and ensuring that environmental considerations are embedded throughout the entire life cycle of the system.

Sustainable equipment and system design

Design and develop equipment that prioritize efficiency and environmental impact while reducing operational costs. Design choices should aim to make the best use of resources, reduces waste, and creates adaptable, efficient spaces [1]. Design should focus on energy-efficient systems, renewable energy, sustainable materials, and building orientation for natural light and passive heating and cooling. Modular construction and flexible design provide opportunities for changes in location and new operational paradigms [1].

Minimizing over-design reduces material use, carbon footprint, and costs, creating spaces that meet needs and support long-term sustainability. Design should facilitate easy maintenance and eventually the ability to rebuild rather than replace by incorporating features such as replaceable wear surfaces or the option to resurface components. Integrate sustainability into design reviews [2] to ensure quality aligns with project and environmental goals.

Develop digitalization and technology strategy

Formulate a plan for integrating digital tools and technologies to enhance productivity, innovation, and sustainability [4]. The adoption of advanced sensor technologies enables the organization to transition from preventive to predictive maintenance and implement real-time monitoring. Identify key technologies—such as robotics, artificial intelligence (AI), data analytics, and automation—that align with organizational goals and address critical areas like resource optimization, waste and emissions monitoring, and process automation [1, 10].

The strategy should outline a framework for evaluating and adopting emerging technologies to remain adaptive and competitive. Use electronic systems for documentation, such as a validation management system, which can reduce manual paper-based activity, simplify processes, enhance data accuracy, and support sustainability by reducing paper waste and the need for physical storage [10].

Step 2. Do: Implement Sustainable Practices

This phase puts planned initiatives into action. Allocate resources, develop action plans, and provide training to ensure understanding and support for the goal. Begin with a pilot phase to test the plan's effectiveness, then scale up based on results.

Apply energy efficiency and sustainable measures

Adopt strategies to minimize energy consumption and incorporate sustainable practices throughout operations, such as upgrading to energy-efficient equipment and installing high-performance insulation to reduce energy use and emissions [1]. During the construction and fabrication stages, promote sustainability by using ecofriendly, low-carbon, or recycled materials, as well as materials that require less water, such as self-curing concrete.

Transitioning to renewable energy sources enhances environmental benefits and some countries offer grant aid or tax reduction for renewable use [1]. Furthermore, integrating sustainability practices into turnover package (TOP) reviews ensures that both quality standards and environmental objectives are met throughout the project life cycle. This can be achieved by verifying that materials, components, and systems meet energy efficiency standards and sustainability requirements as defined in the URS, while also digitizing the TOP management process.

Optimize resource use and waste management

Optimize material usage by recycling and incorporating modular or prefabricated components to reduce on-site waste and enhance resource efficiency throughout operations. This includes selecting sustainable materials, minimizing excess use, reusing or recycling materials, and implementing closed-loop systems [1] where feasible. Develop a waste management plan that incorporates waste segregation, recycling initiatives, and safe disposal methods to minimize landfill contributions [1, 11]. Regularly evaluate and improve the material use and waste practices for betterment [6].

During the commissioning phase, sustainability is promoted by ensuring that all equipment meets environmental standards,



thereby reducing energy consumption and minimizing pollution. Commissioning plays a key role in executing sustainability objectives. It ensures that systems perform as intended according to user and design requirements, including sustainability-related specifications. This phase allows teams to functionally test and document that sustainability requirements are fully implemented and verified, without entering the regulated GMP space. Baseline testing for resource usage, like for energy and water, is conducted to establish reference points for future performance monitoring and to drive sustainability improvements.

Additionally, sustainability testing should assess potential negative impacts of commissioning activities. If any issues are identified, corrective actions—such as system fine-tuning, adjustments, and balancing—are implemented to reduce both environmental and operational impacts [1]. For example, adjusting cleanroom air change rates based on occupancy reduces energy use by lowering ventilation when rooms are empty. An occupancy-based control system lowers energy costs and boosts efficiency, but it must be validated to ensure compliance with environmental standards and regulations [1, 12]. The commissioning process should be coordinated with the engineering quality system to ensure that the sustainability-related commissioning is coordinated with patient safety requirements [1].

Sustainable procurement and supply chain management

Evaluate and prioritize suppliers that demonstrate strong environmental and social practices through vendor qualification. Prioritize recyclable and biodegradable materials in packaging wherever possible and reduce transportation's environmental impact by optimizing routes and using fuel-efficient vehicles [7]. Establish material take-back programs with suppliers for packaging and other materials used during project and routine operations [1, 4]. The goal is to recycle, refurbish, or dispose of these materials rather than sending them to a landfill [11].

Implement and adopt smart technology

Use smart technology to boost efficiency, cut resource use, and meet sustainability goals. This includes real-time tracking of resources, using AI for streamlined operations, and automating systems to reduce waste [1, 10]. Smart technology enables data-driven decisions, predictive maintenance, and transparency in resource management, supporting ongoing sustainability improvements. Instead of practicing traditional validation, use continued process verification (CPV) to monitor and validate processes in real time, reducing the need for revalidation and minimizing waste [1].

Embed a culture of sustainability

Foster a culture that prioritizes sustainability at every level in an organization. Conduct trainings, awareness programs, and workshops on sustainability to train and transfer knowledge to the team [1]. Encourage sustainable practices in daily operations, recognize achievements, and involve teams in sustainability initiatives to promote shared responsibility. A strong sustainability culture drives lasting commitment and innovation, aligning individual actions with the organization's long-term environmental and social goals.

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Step 3. Check: Verify, Monitor, and Measure Performance

This phase is essential for verifying and assessing the effectiveness of implemented sustainability strategies. Monitor and analyze performance to see if objectives are met or need adjustment.

Periodic verification of key sustainability metrics

Verify and monitor KPIs to evaluate the performance and identify areas for improvement. By consistently tracking and analyzing KPIs, organizations can effectively measure their progress and identify opportunities for enhancement. By incorporating sustainability checkpoints into the test protocol, we can monitor utility consumption and optimize equipment utilization to ensure operations align with efficiency and environmental goals. Additionally, testing protocols, consumables, and other resources used during periodical verification should align with sustainable principles. This involves implementing automated or digital solutions to reduce paper-based documentation, integrating training activities with protocol execution, eliminating duplicate work, and establishing a utility leak monitoring program, as examples [1].

Analyze data and identify trends

Evaluating data trends reveals the effectiveness of sustainability practices. Periodic evaluation helps identify new opportunities to adopt green technologies or system upgradations, ensuring

ongoing environmental benefits. A well-structured preventive maintenance program should be in place to prioritize the use of ecofriendly materials, minimize waste, and extend equipment lifespan. Regular monitoring and review enable teams to analyze KPIs and spot trends, fostering continuous improvement [1]. For example, metering all utilities such as air, steam, and water allows for real-time monitoring of consumption, which helps in optimization. Tracking energy consumption over time can also highlight the impact of energy-efficient equipment on overall power usage [1, 12]. The data can be used to document, benchmark, monitor, and report energy use; optimize equipment utilization; and drive strategic improvements [1].

Conduct regular audits

Regularly assess sustainability efforts through internal and external audits. This includes reviewing data accuracy, identifying areas for improvement, and ensuring compliance with industry standards like ISO 14001 (Environmental Management Systems) and ISO 50001 (Energy Management Systems) [13, 14].

Assess end-of-life or decommissioning strategy

Evaluate strategies for handling equipment or facilities that are no longer needed to minimize environmental impact. This involves planning how to safely dispose, recycle, or reuse facilities and equipment while considering impacts like waste and pollution on the environment. If equipment still has a useful life, consider selling it on the used equipment market. Prioritize options that support circular economy principles, such as refurbishing or reclaiming materials, and ensure compliance with regulations [1, 7]. This includes options for dismantling components, such as instruments and electronic items, that can be salvaged or repurposed.

A well-defined decommissioning strategy helps reduce waste, conserve resources, and mitigate long-term environmental risks [6]. Sustainable decommissioning also involves managing hazardous materials safely to prevent environmental contamination. By using ecofriendly disposal methods and considering the environmental impact of decommissioning activities, the process can reduce its carbon footprint and contribute to a circular economy. Additionally, decommissioning plans should account for restoring the site to a condition that supports future sustainable use.

Gather feedback

Obtain feedback from stakeholders, including employees, customers, and suppliers, to determine how well sustainability initiatives are being received and what areas might need improvement [1].

Step 4. Act: Continuous Improvement

Sustainability can be achieved through continuous monitoring and improvement during routine operations [1]. Implementing standard operating procedures (SOPs) for sustainable practices and providing employee training are essential. Use insights from previous phases to improve sustainability strategies by implementing corrective actions and expanding successful initiatives across the organization. Staff should be educated on these practices and encouraged to contribute ideas for continuous improvement. Effective change management must be integrated throughout the entire system life cycle [6].

Implement improvements

Based on the findings from the monitoring phase, make necessary adjustments. For example, if waste-reduction targets are not met, reassess waste management practices and identify more effective solutions.

Scale successful initiatives

Replicate and expand effective sustainability practices to other areas of the business. For example, if a pilot project on renewable energy in one facility proves successful, scale it to other manufacturing sites.

Set new sustainability goals

As the organization progresses and sustainability becomes more embedded in its operations, set new goals that further enhance the commitment to environmental and social responsibility.

Incorporate circular economy principles

Design products and processes to maximize resource efficiency, minimize waste, and promote reuse. This involves prioritizing reusable, recyclable, and renewable materials; extending product life cycle through repair or refurbishment; and creating closed-loop systems where waste serves as input for new products while meeting code and compliance requirements [6, 7]. Implementing circular economy principles reduces dependency on finite resources, lowers environmental impact, and supports long-term sustainability by maintaining value within the production cycle and reduces landfill contribution [6, 7, 11].

Communicate lessons learned

Share insights and best practices from sustainability initiatives with all stakeholders. Document challenges, successes, and impacts to guide future projects and support continuous improvement. Facilitate knowledge-sharing sessions, publish case studies, and provide transparent reports to boost understanding, collaboration, and commitment to sustainability goals while strengthening organizational knowledge and to fuel innovation [6].

By embedding sustainable practices throughout every project phase, we reduce environmental impact while reaping long-lasting, cost-effective solutions that enable greener choices without compromising quality, safety, or compliance.

BENEFITS

Integrating sustainability practices offers several benefits, particularly resource and cost savings, aiding with regulatory compliance and risk mitigation, unlocking market advantages, and improving operational efficiency.

Reducing energy, water, and material consumption translates into significant cost savings over time. Efficiency improvements

can lower operational expenses and enhance profitability. In addition, many regulatory bodies are incorporating sustainability considerations into their guidelines. Implementing sustainable practices ensures compliance with evolving regulations and reduces the risk of noncompliance.

Embracing sustainability also enhances a company's image and can create a competitive advantage, as stakeholders increasingly favor environmentally responsible organizations. By obtaining recognized sustainability certifications and integrating green practices into design, operations, and supply chains, companies can not only improve their environmental impact but also differentiate themselves in the market, attracting eco-conscious consumers, investors, and partners. Lastly, sustainable practices streamline processes, making them more efficient and less resource intensive. This can lead to shorter qualification timelines, which then leads to quicker turnaround and reduces operational cost.

CHALLENGES

Despite the benefits, there are challenges associated with integrating sustainability practices. First, these practices can require a high initial investment. Although sustainable technologies and practices offer substantial long-term cost savings, the high upfront investment required can be a barrier for some organizations. Also, demonstrating cost effectiveness at the beginning is challenging, as many benefits only become evident over time [1].

Second, meeting sustainability objectives while complying with stringent regulatory standards may require careful planning and innovative approaches. Companies must ensure that sustainable practices do not compromise product quality or safety. Finally, transitioning to sustainable practices requires specialized knowledge, and training staff to adopt these practices can be challenging. Until the first adopters prove that inclusion of sustainability-based formats provides a significant payback, sustainability is unlikely to be adopted by the rest unless forced by regulations or through conscience [1].

CONCLUSION

Sustainability is no longer a future goal; it is a pressing necessity. Applying GEP provides a structured and practical foundation to implement sustainability throughout the project life cycle. From design to procurement and construction to testing, GEP enables consistent decision-making aligned with sustainability objectives without compromising compliance or product quality. This approach not only benefits the planet, but it can also lead to long-term cost savings, a reduced carbon footprint, and a win-win situation for both the environment and the organization. Implementation challenges, including upfront costs and regulatory alignment, can be balanced by integrating key enablers such as digitalization, green chemistry, smart technologies, and sustainable procurement.

By embracing sustainable practices such as energy efficiency, digital documentation, resource optimization, leverage testing, and waste reduction, organizations can significantly minimize their environmental impact. Achieving this vision requires collaboration, knowledge-sharing across regions, and the adoption of best practices to overcome challenges and build a healthcare system that is both patient focused and environmentally sustainable.

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