Optimizing Cost Efficiency in High Performance Buildings Through Commissioning

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Abstract

High performance buildings such as BSL laboratories require highly specialized building systems and operational protocols to ensure safety, regulatory compliance, and operational efficiency. As a result, the life cycle costs of such facilities—including energy consumption, maintenance, and operational expenses—are substantial. Commissioning has consistently been shown to reduce these costs before, during, and after construction while also enhancing performance, regulatory compliance, and sustainability.

The Cost Challenges of BSL Laboratories

BSL laboratories are among the most expensive to design and build. Although costs vary significantly depending on the BSL level, the size, the location, and the complexity of the planned facilities (among many other factors), a report by Cushman & Wakefield found that the average fit out[1] cost for BSL-3 laboratories in the United States was approximately $16,000 USD per m2 in 2024, with costs reaching $21,500 USD per m2 in some markets.[2] These costs represent an increase over 2023, and the report's authors note that ongoing supply chain issues and rising prices of certain commodities could continue to push costs up. The cost for fitting out BSL-4 spaces, which not only require more complex systems but also 600 m2 of support space for every 93 m2 of lab space, soared to around $28,000–$35,000 USD per m2 in 2024, with projections indicating a 30% increase for new builds.

In addition to the investment in designing, building, and equipping containment laboratories, there are ongoing costs related to facility operation—more than a decade ago, experts noted that the cost of building a BSL-3 facility can be four times that of a

[1] Fit out costs are those expenses involved in making an unfinished space fully functional, in this case as a laboratory. This includes partitions, specialized equipment, benching, HVAC and automation controls, electrical and plumbing systems, pass boxes, cabinets, etc.

[2] Original figures were given as costs per square foot and have been converted. See: Cushman & Wakefield (2024) *Life Sciences Fit Out Cost Guide*. Available at: https://cushwake.cld.bz/Life-Sciences-US-Fit-Out-Cost-Guide-2025.

BSL-2, stressing that this can increase up to 800% when operational costs are taken into account.[3] According to R. Heckert and his co-authors, annual maintenance of high containment facilities can be as high as 15% of the original construction cost.[4] A 2012 study[5] estimated maintenance and engineering costs for BSL-3 spaces to be approximately $968 per m2, while for BSL-4 spaces, the cost was significantly higher, at $2,454 per m2. These figures are consistent with numbers reported by the Australian Animal Health Laboratory (AAHL) in 2011—annual maintenance and operational costs were approximately $2,400 per m2, (totalling $6.8 million AUS) for its BSL-3 and 4 high-containment facilities.[6] In terms of total costs, a report of the WHO Consultative Meeting on High/Maximum Containment (Biosafety Level 4) Laboratories Networking in 2017 noted that the average operating costs of four BSL-4 labs in the United States was between $8–13 million per year. For maximum containment facilities, operational costs are cited as being more than 10% of the initial construction cost.[7]

[3] Abad, X. (2010) "Reflections on Biosafety: Do We Really Know What Biosafety, Biocontainment, and Biosecurity Mean?" *Contributions to Science*, 6(1). Available at: https://www.researchgate.net/publication/236944754_Reflections_on_biosafety_do_we_really_know_what_biosafety_biocontainment_and_biosecurity_mean.

[4] Heckert, R. A., et al. (2011) "International Biosafety and Biosecurity Challenges: Suggestions for Developing Sustainable Capacity in Low-Resource Countries." *Applied Biosafety*, 16(4). A 2017 assessment by NIAID found that annual operating costs for BSL-4 facilities were between 5–8% of the original construction costs. See also: le Duc, J. W. (2020) "Biocontainment Laboratories: A Critical Component of the US Bioeconomy in Need of Attention." *Health Security*, 18(1). Available at: https://doi.org/10.1089/hs.2020.0002. The WHO report (op cit.) put this at 10%.

[5] Original figures were given as costs per square foot and have been converted. See: Tradeline (2012) *Benchmarking Operational Costs at Containment Facilities*. Available at: https://www.tradelineinc.com/reports/2012-11/benchmarking-operational-costs-containment-facilities#:~:text=When%20the%20adjustments%20were%20factored,reasonable%20job%2C”%20explains%20Langevin.

[6] Committee on Anticipating Biosecurity Challenges of the Global Expansion of High-Containment Biological Laboratories; National Academy of Sciences; National Research Council (2011) *Biosecurity Challenges of the Global Expansion of High-Containment Biological Laboratories*. Available at: https://www.ncbi.nlm.nih.gov/books/NBK196156/.

[7] World Health Organization (2018) *Consultative Meeting on High/Maximum Containment (Biosafety Level 4) Laboratories Networking*. Available at: https://iris.who.int/bitstream/handle/10665/311625/WHO-WHE-CPI-2018.40-eng.pdf.

The primary factor contributing to the high operating costs of these facilities is their intensive energy consumption. In 2011, PG&E reported[8] that laboratories consume between five to 10 times more energy per square foot than typical office spaces, while specialty labs with clean rooms and large processing loads can consume up to 100 times more; in the same year Hopkinson et al. found that laboratories in the UK consumed more than 730 Kwh per m2 per year.[9] That figure is in the middle of the range that PSE calculated a decade later of 30–100 Kwh per square foot per year (approximately 335–1075 Kwh per m2), and 75,000–800,000 Btu of natural gas.[10] The majority of this energy demand is driven by systems and processes that are vital to the safe operation of the building and the well-being of personnel and the surrounding community—air changes, cleanrooms, heating and air conditioning—all of which require energy-intensive air handling and HVAC systems. Energy use in these systems is typically much higher than in standard office buildings or even typical healthcare facilities. According to a 2011 study of laboratory energy consumption, up to 60% of the total energy use by chemistry laboratories and up to 45% by life science laboratories was ventilation-related.[11] Other experts have suggested that HVAC systems account for more than 60% of a laboratory's total consumption.[12] [13]

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[8] PG&E (2011) *High Performance Laboratories: A Design Guidelines Sourcebook*. Available at: https://www.pge.com/assets/pge/docs/save-energy-and-money/rebate-and-incentives/Labs_BestPractices.pdf.

[9] Hopkinson, L., et al. (2011) "Energy Consumption of University Laboratories: Detailed Results From S-Lab Audits." Available at: https://www.mygreenlab.org/uploads/2/1/9/4/21945752/ie_-_energy_consumption_of_univeristy_laboratories_-_s-labs.pdf.

[10] PSE (2021) *Laboratories*. Available at: https://pse.bizenergyadvisor.com/article/laboratories. See also: https://www.aircuity.com/wp-content/uploads/Energy-Intensive-Life-Sciences-Labs-Havent-Discovered-Transparent-ESG-Reporting-Bisnow.pdf for data from 2023.

[11] Hopkinson, L., et al. (2011).

[12] Rush, J. (2021) "Is HVAC the Key to Energy Efficient Laboratory Design?" *BES*, 29 January. Available at: https://www.besltd.org/media-centre/is-hvac-the-key-to-energy-efficient-laboratory-design/. Love, A., Spangler, B., & Klee, C. (2013) "Reducing HVAC Energy Consumption in Lab Buildings." *Payette*, 2 April. Available at: https://www.payette.com/research-innovation/reducing-hvac-energy-consumption-in-lab-buildings/#:~:text=Of%20the%20total%20annual%20energy,air%20conditioning%20(HVAC)%20systems. Source, E. (2013) "Energy Improvements." *Lab Manager*, 3 April. Available at: https://www.labmanager.com/energy-improvements-10613.

[13] It is important to note that many of these studies are more than 10 years old, and improvements in the energy efficiency of HVAC and related systems, along with the increasing use of commissioning

Commissioning and Its Role in Cost Optimization

One way to mitigate these costs (and others) is through commissioning (Cx), defined very generally as "a systematic process intended to verify and document that new and existing building systems operate according to the building design and the owner's operating requirements."[14] Unavoidably, commissioning will add another line to already large budgets. A comprehensive commissioning plan can cost an amount equivalent to between 1.5–3% of the total construction cost and owners may be tempted to consider it to be an "extra," and therefore discretionary, cost. However, it has been repeatedly confirmed through increasingly data-rich studies that commissioning is worth the investment. Savings gained through reduced energy demands, extended equipment life span, on-time delivery, and error avoidance (among many other benefits) allow owners to recoup their investment in commissioning in as little as 1.1 years for existing construction and 4.2 years for new construction projects.[15]

Commissioning plays a vital role at all stages of a building's life cycle, from planning and design through to ongoing operation and maintenance. Pre-construction commissioning provides the opportunity to review designs, systems, and expectations before the construction process begins. A key goal at this stage is to ensure that the selected equipment and systems are appropriate for the building's intended functions. Comprehensive documentation of all systems and plans is also developed at this stage. Commissioning before construction begins also makes it possible to identify potential design flaws and compliance violations, both of which are far easier and less expensive to resolve at this stage. Also important at this stage is to ensure that everyone involved—including architects, engineers, commissioning agents, biorisk professionals, and

strategies to optimize laboratory systems, have likely reduced HVAC energy demands in both relative and absolute terms.

[14] Crowe, E., et al. (2020) "Building Commissioning Costs and Savings Across Three Decades and 1,500 North American Buildings." *Energy and Buildings*, 227. Available at: https://doi.org/10.1016/j.enbuild.2020.110408.

[15] Mills, E. (2009) *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*. Lawrence Berkeley National Laboratory Report. Available at: https://eta-publications.lbl.gov/sites/default/files/building_commissioning_-_a_golden_opportunity_for_reducing_energy_costs_and_greenhouse-gas_emissions.pdf.

owners—are “on the same page” with respect to the overall goals and requirements of the project as well as their specific roles in making sure those are met.

During the actual construction process, the focus of commissioning shifts toward ensuring that systems and equipment are properly installed, integrated, and are functioning as intended. This involves testing to identify poorly performing systems and troubleshooting to resolve any issues before the building becomes operational. It is also at this stage that the construction can be reviewed to make sure that the installation meets the specifications laid out in the design documents and that relevant codes and standards are being observed. Training issues can be addressed at this stage to make sure that operators understand how to properly maintain and operate the systems and equipment.

After construction, as the building goes into full operation, commissioning ensures that all systems and equipment are operating as expected and required. This involves troubleshooting and making adjustments to any system that is incorrectly installed or malfuncioning. It may also involve fine-tuning to ensure that everything is optimized for energy consumption. Post-construction commissioning, ideally, will be ongoing. Across the life cycle of a building, re-commissioning equipment and systems can ensure that they remain at peak performance—periodic inspections, ongoing maintenance of equipment, recalibration or repairs of systems, and ongoing optimization are all part of the ongoing commissioning process.

Energy Savings

As electricity and natural gas prices continue to rise, high-performance buildings such as containment laboratories and pharmaceutical facilities will have increased operational costs given their heavy energy demands. As described in an article prepared for Savills in 2023, a lab in Spain saw its energy costs increase by 60% in 2021–22 and cited predicted increases for larger European life science facilities of up to tenfold compared to 2021.[16] Not surprisingly, then, energy savings is one of the most important aspects of the commissioning process.

[16] de Rijk, B. (2023) *Skyrocketing Energy Bills for Life Sciences*. Savills. Available at: https://www.savills.com/research_articles/255800/345762-0.

According to Mills, high performance buildings, in particular, are "the commissioning mother load"—both the percentage and absolute savings that can be achieved in these buildings are significantly higher than in other types due to their energy intensity. He also found that payback times of commissioning investments for high performance buildings are among the lowest of all types of buildings. Research by E. Mills, E. Crowe, and others[17] demonstrates that commissioning building systems to ensure that HVAC, lighting controls, and other energy-consuming components are installed and operating according to design intent can yield substantial cost savings of 10–20% in new buildings, and up to 30% in existing buildings. A study tracking the energy consumption of a building over a 20-year period found that its heating and cooling consumption had increased more than 12% in only two years, of which almost 75% of which was attributed to component failures and control changes.[18] The "drift" of building performance in this way can be corrected by ongoing commissioning.

Timely Project Delivery and Error Avoidance

Timely project delivery is another, often unrecognized, benefit of commissioning both before and during construction. Mills found that commissioned buildings were 20% more likely to be completed on schedule compared to non-commissioned projects, a factor that directly impacts project costs. In part this is because careful design review and planning before construction can ensure that the construction process is well-organized and well-timed. Commissioning during construction can reduce the potential for errors and avoid the need for rework. As noted by the Prometheus Group, rework to correct construction errors can cause significant delays and additional project costs. The primary factors leading to rework include poor planning and design errors, inadequate communication, failure to apply quality control measures to ensure early error detection,

[17] Studies supported by the U.S. Department of Energy and conducted by the Lawrence Berkeley National Laboratory and the Building Commissioning Association include the 2020 study by Crowe et al. of 1,500 North American buildings, including high-performance buildings, as well as the 2004 study by Mills et al. (*The Cost Effectiveness of Commercial-Buildings Commissioning: A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States*), and the 2009 study by Mills.

[18] Claridge, D. E., et al. (2004) "Is Commissioning Once Enough?" *Energy Engineering*, 101(4). Available at: https://doi.org/10.1080/01998590409509270.

and changes in the client's requirements.[19] All of these can be largely mitigated by commissioning both before and during construction.

At the beginning of a project, commissioning can "right-size" systems and components before they are purchased/installed, thereby reducing costs associated with changes/retrofits, requests for information, contractor callbacks, and construction delays. Dorgan et al. offered examples in which new-construction commissioning saved up to $500,000 in project delivery costs. Based on the cases they analyzed, these non-energy benefits of commissioning can be worth up to 22 times the costs of the commissioning process itself.[20] Similarly, D. Frenze et al. reported that a laboratory at the Lawrence Berkely National Laboratory was able to save approximately $2.5 million—over 4% of the total construction costs of the project—simply by right-sizing their mechanical and electrical systems.[21]

Extended Lifespan and Reduced Maintenance Costs

As described above, prior to construction, commissioning plays a key role in ensuring that the planned systems and equipment have been right-sized. In this context, not only can savings be gained by making sure that buildings have not over-estimated their needs, but they can also be realized by ensuring that the system requirements have not been under-estimated. Containment systems experience substantial wear and tear due to continuous decontamination cycles, high demand for airflow control, and the constant operation of safety systems. Commissioning at the design stage can help to minimize this wear and tear by ensuring that the selected systems and equipment are able to meet these requirements without undue stress.

Crowe's research indicates that buildings subjected to comprehensive commissioning—especially during the construction phase—experience fewer maintenance-related issues

[19] Prometheus Group (2024) *Strategies to Eliminate Rework in Construction Commissioning, Completions, and Handovers*. Available at: https://www.prometheusgroup.com/resources/posts/strategies-to-eliminate-rework-in-construction-commissioning-completions-and-handovers.

[20] Dorgan, C. R., Cox, R., & Dorgan, C. (2002) "The Value of the Commissioning Process: Costs and Benefits." USGBC Greenbuild Conference, 2002, cited in Mills (2009).

[21] Frenze, D., et al. (2005) *Laboratories for the 21st Century: Best Practice Guide: Right-Sizing Laboratory Equipment Loads*. Available at: https://www.osti.gov/servlets/purl/922847.

and require less frequent costly repairs. T. Peters reports that these savings can reduce maintenance costs by up to 20% annually.[22] For buildings in operation, ongoing commissioning helps identify signs of deterioration early, enabling targeted, preventative maintenance that can prevent costly repairs—this is significant given the finding by Shen et al. that a preventative rather than reactive strategy can reduce long-term operational costs by as much as 30%.[23] Further, by ensuring that systems are functioning at peak efficiency and optimal energy usage, commissioning at this stage also plays a critical role in extending the lifespan of vital building equipment; Mills found that, in addition to optimizing energy performance, commissioning enhances the overall functionality and reliability of HVAC and electrical systems by reducing excess wear and tear, reducing failures and therefore also the cost of repairs or replacements.

Summary

This brief review highlights just some of the many benefits of commissioning. As an investment that pays for itself, commissioning produces significant savings for high-performance buildings, for which cost-efficiency is a concern at every stage, from planning and design to operations and maintenance. Commissioning has been shown to improve energy efficiency, reduce costly errors, contribute to on-time delivery, and help control operation and maintenance costs by optimizing systems and equipment. For all of these reasons (among others), commissioning should be considered an indispensable part of the process across the entire lifespan of a laboratory.

[22] Peters, T. (n.d.) "Beyond Sustainability: How Commissioning Cuts Costs & Boosts ROI." *Kode Labs Blog*. Available at: https://kodelabs.com/resources/beyond-sustainability-how-commissioning-cuts-costs-boosts-roi/.

[23] Shen, Y., et al. (2023) "A Comprehensive Review of Building Maintenance Strategies: From Reactive to Proactive Approaches." *Journal of Building Engineering*, 55, 104926. Available at: https://doi.org/10.1016/j.jobe.2022.104926.