Roadmap to Building a Smart Laboratory

Bridging the gap between operational efficiency and occupant experience to realize the intelligent lab infrastructure of tomorrow

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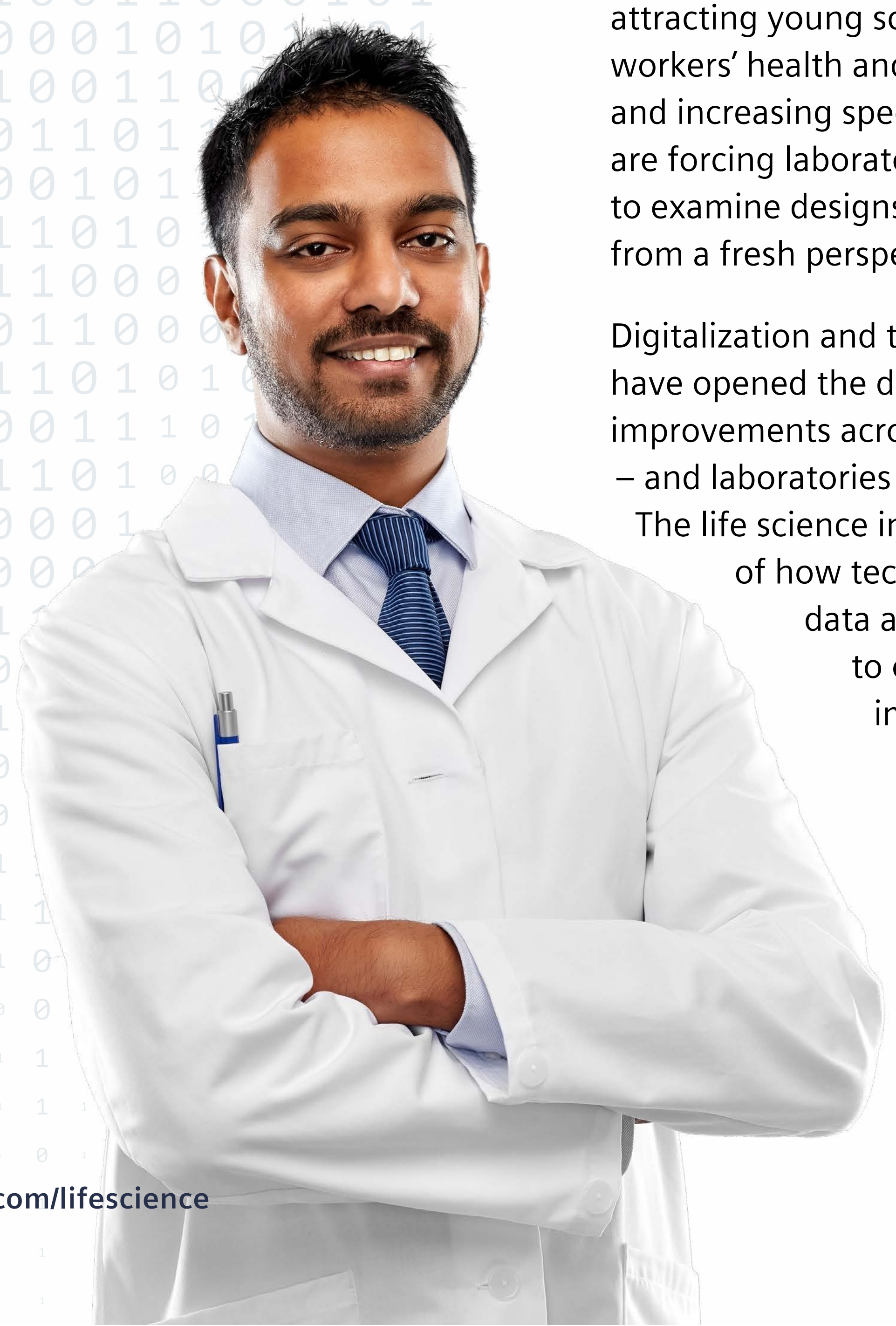
Executive Summary



Life science organizations are facing increasingly difficult challenges in today's environment. From meeting changing regulations, improving energy efficiency and attracting young scientists, to protecting workers' health and safety, reducing costs, and increasing speed to market. All of these are forcing laboratory owners and managers to examine designs and operating procedures from a fresh perspective.

Digitalization and the Internet of Things (IoT) have opened the door to significant operational improvements across all verticals and facilities – and laboratories have been no exception. The life science industry is abuzz with ideas of how technological innovations and data analytics can be leveraged to optimize performance, improve design/architecture, enhance occupant comfort, and prepare labs for future innovations.

Despite the positive momentum, many laboratories today continue to rely on aging equipment, disconnected building systems, and reactive maintenance strategies for safe and efficient operation. These labs often operate independently of occupants, under a set of predetermined conditions dictated by their design. They also afford limited visibility into their performance, which makes monitoring energy usage virtually impossible, while negatively impacting organizational initiatives related to health and safety, talent recruitment and retention, and securing valuable grant opportunities.

To address these challenges, owners and managers must begin to move beyond the basic digital conversations today and strive toward the adoption of an integrated facility approach that enables the creation of Smart Lab infrastructure of tomorrow. A Smart Lab is one that leverages a holistic optimization strategy based on data, predictive capabilities, digital services, and total room automation to reduce energy consumption, improve health and safety, increase employee productivity, and foster innovative research and development.

This resource aims to help lab owners and managers achieve these goals by:

- Outlining the challenges labs currently face
- Discussing how IoT and digitalization are impacting the way laboratories are managed/operated and the drivers behind the need for more intelligent infrastructure
- Defining what a Smart Lab is and visioning what the future could look like
- Outlining the steps owners and managers can take to begin transforming their facility into a Smart Lab

CHAPTER 1 – Laboratory Market Overview and Challenges

According to the International Institute for Sustainable Laboratories (I2SL), there are more than 10,000 labs in North America and at least twice that many worldwide [1]. Although these labs vary in age, function, and level of technological sophistication, a large majority of them continue to be a drain on energy. Energy consumption per square foot in laboratories is on average 5-10 times higher than in standard commercial office buildings [3]. In some cases, specialty laboratories can consume 100 times the energy of similarly-sized commercial facilities.

Much of this attributable to the fact that air quality requirements greatly exceed those of other buildings. Laboratories are often designed for ventilation rates between 6-20 air change rates per hour (ACH). By comparison, a standard office building requires <1 ACH.

Among all the factors that to contribute to energy consumption in a laboratory, one of the most significant is fume hoods.

ONE LABORATORY FUME HOOD CAN USE AS MUCH ENERGY IN A YEAR AS THREE AVERAGE U.S. HOUSEHOLDS COMBINED.

OVERALL, APPROXIMATELY 60%

OF LABORATORY ENERGY BILLS GO TO HVAC SYSTEMS THAT NEED TO PROTECT OCCUPANTS FROM AIRBORNE HAZARDS [4].

The way in which occupants interact with the lab environment also plays a role in energy consumption. From running lights and equipment at full capacity around the clock, to leaving fume hoods open, the manual process of interacting with a lab space can significantly impact efficiency, safety, and compliance. It can also lead to poor temperature regulation, underutilization of equipment assets, and increased maintenance.

- For outdated laboratories that rely heavily on a high number of human touchpoints, there are significant opportunities to reduce utility consumption, improve sustainability, and manage costs through systems integration and digitalization
- To execute that vision, however, requires continuous monitoring, total room automation, and proactive data analysis to harmonize operational efficiency with occupant experience
- This convergence between facility operation and lab R&D activities allows stakeholders to increasingly think in terms of space collaboration, efficiency and design to make their spaces more intelligent and better equip tomorrow’s generation of lab scientists to meet market demands.

CHAPTER 2 – The Need for Infrastructure

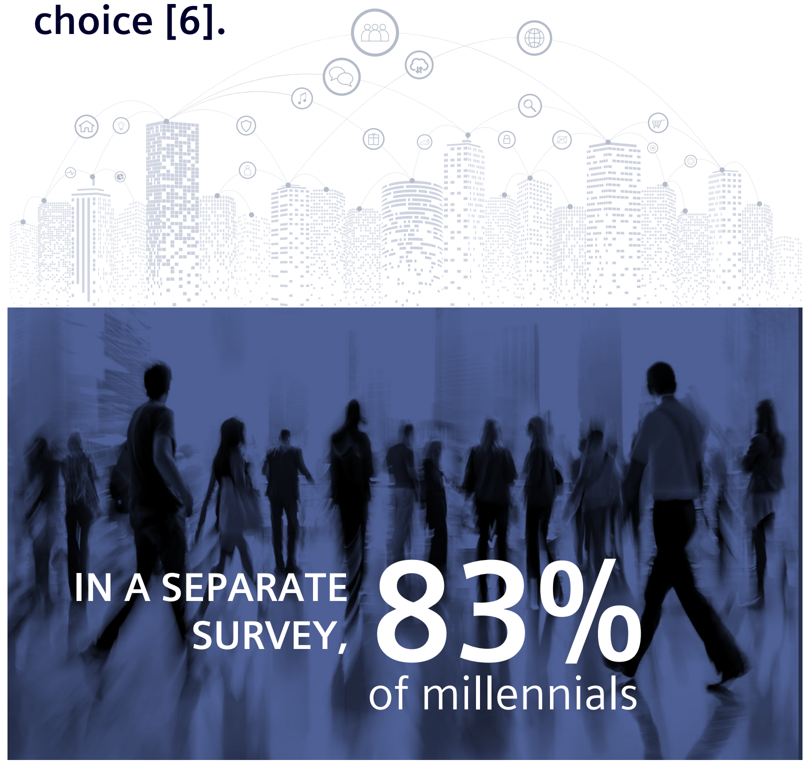
In addition to reducing energy consumption and increasing visibility into the performance of critical systems, there are a number of market factors driving the need for more intelligent infrastructure across today's laboratories. Some of these include:

- Younger generation of scientists entering the workforce – Gen Zer's are widely considered to be the first "fully digital" generation, and by 2021, they will represent approximately one-fifth of the total workforce [5]. The vast majority of these young individuals expect digital tools and capabilities to be part of their workplace experience. At home, they can adjust their heat, turn on lights, and check their garage door status, all from their phone. The expectation is that they have the same type of control and monitoring at their place of business. Given this reality, organizations that are not leveraging digital as part of their core operating strategy will be at an inherent disadvantage to those that are when it comes recruitment and retention.

Additionally, data increasingly shows that younger individuals are placing a greater focus on sustainability.

In a 2018 survey **63% of students**

said a college's commitment to the environment affects their attendance choice [6].



said they would be more loyal to organizations that are socially and environmentally conscious in their organizations [7].

Overall, in 2016, young professionals (persons aged 20 through 34) made up 28% of the professional workforce (17.2 million professionals). The life, physical, and social science occupation had the highest concentration of this demographic at 35.9% [8].

- **Digital transformation and rapid technological adoption** - Perhaps the biggest driver of intelligent lab infrastructure is the inevitable fact that our world is increasingly becoming even more connected and digital. There is no slowdown in innovative technology adoption, and thus, no slowdown in data growth. Quite simply, it is no longer a question of if the life science industry will undergo full-scale digital transformation – it is a matter of when. Digital technologies.

In a recent survey, nearly three-quarters of life sciences executives said they believe that artificial intelligence (AI) will significantly impact the industry and one-third said they are aggressively taking steps to participate in digital ecosystems [9].

said that adopting platform-based business models and engaging in ecosystems of partners, to define, develop, supply and commercialize innovative products and solutions is critical to their success.

Demand for "open" versus "closed" labs
Increasingly, today's scientists are pushing for open laboratory design concepts that enable more effective research and development through collaboration. In these labs, equipment, bench space, and support staff are often shared. This places greater demands on the facility systems and can increase risk if not properly managed (i.e., more standing in front of fume hoods for longer periods of time). Addressing these new challenges requires modern equipment and integrated digital technologies to provide real-time visibility into the laboratory environment so that airflow, ventilation, lighting control, and lab security can all be managed safely and efficiently.

In recent years, an increasing number of organizations have recognized the impact of these trends and have begun taking steps to digitalize their laboratories. Most, however, have yet to implement a truly holistic digital strategy and continue to leverage technologies in piecemeal fashion.

Much of this is can be attributed to siloed decision-making. Often times, personnel tasked with managing building infrastructure, such as security, fire safety, HVAC, lighting, etc., make purchasing decisions in a "vacuum" – that is to say they do not consider how one system impacts another and the benefits of allowing them to talk to each other.

Failure to recognize the interplay between building systems and the digital solutions supporting them can lead to increased energy consumption, higher costs, and a highly inflexible lab environment -- all of which negatively impacts occupants. Ultimately, low-level system integration only provides partial visibility, creating challenges and inefficiencies that prevent laboratories from capturing all that digital transformation has to offer.

"Old-school" thinking, particularly when it comes to interpreting regulatory requirements, has also hampered digital adoption. Take, for example, a vivarium. Traditionally, it has been the approach of lab managers to simply meet the ACH figure recommended by applicable guidelines.

However, in certain cases, the guidelines may allow for a lower ACH to be set if it is determined that air quality and animal health are not being negatively impacted. The latter approach can enable significant energy savings for facilities with multiple animal holding areas. However, an investment in digital technologies to monitor the environment is required.

Another salient example of how digitalization can help organizations improve compliance relates to the transmission of pharmaceutical manufacturing and research data over the internet. Many laboratories interpret regulations to mean that data cannot be communicated via a network, when in fact the requirement is that such data can be transmitted, so long as it is not able to be changed or adulterated in any way. This requirement can be satisfied by storing data on servers in the cloud. This can yield significant benefits for organizations, particularly those that that manage multiple laboratories, including lower IT costs, greater flexibility, and an increased ability to scale.

CHAPTER 3 – The Makings of a Smart Lab

Despite the aforementioned hurdles, the time has come to move past the concept of their lab as an isolated space and energy consumer, and instead view it as a partner in your success. New technologies and changing regulations create opportunities to save energy, reduce operating costs, and gain a competitive edge by creating Smart Labs of tomorrow.

A Smart Lab utilizes a holistic, digital optimization strategy that begins with a Green Labs Solution (GLS) approach. This approach is based on data, predictive maintenance, digital services and total room automation to improve lab performance and occupant comfort, and foster future innovative research and development.

Unlike traditional labs, which operate independent of occupants, a Smart Lab is capable of detecting and reacting to its users and their activities. Transforming the space from being predefined and inflexible to highly adaptive.

The GLS approach leverages a wide range of services, technologies and facility-improvement measures (FIMs) to reduce lab energy consumption through a comprehensive approach to personnel safety, compliance and occupant comfort. The process begins with an assessment of current end-user lab operations and data to:

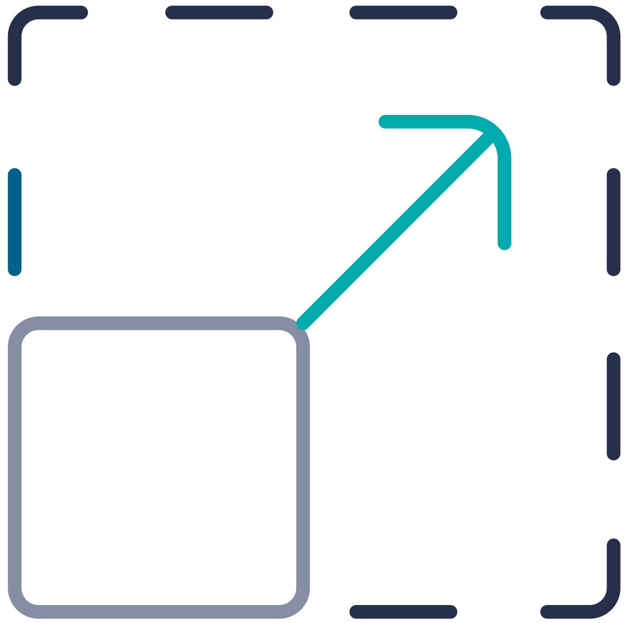
- Understand key stakeholders' facility objectives
- Implement energy-saving technologies and solutions
- Maintain optimal energy efficiency with proper ongoing facility operations management

THE PROCESS CONTINUES BY ADDING A LAYER OF INTELLIGENCE THROUGH A CENTRALIZED ANALYTICS PLATFORM, WHICH ENABLES THE USE OF DIGITAL APPLICATIONS AND SERVICES.

Together, through the implementation of smart infrastructure and digital applications, lab end-users can harness the power of their data to transform their laboratories into dynamic assets that can be continuously optimized.

The key components of a Smart Lab include:

- **An Integrated Building Management System (BMS)**



An open, scalable and integrated BMS which provides centralized command, control, and visibility into key building systems, including automation, fire safety, security, lighting, and HVAC, is a prerequisite for creating a smart laboratory. Many laboratories today utilize multiple platforms to manage these critical systems – and the vast majority are not connected. Failure to recognize how the dynamic operation of one system impacts the others limits opportunities for energy savings and makes optimization virtually impossible to achieve. It also has implications for safety.

Consider, for example, an emergency event, such as a fire or chemical spill. In a laboratory with disconnected systems, the alarm sounds, informing occupants that they need to evacuate immediately.

If in fact the fire or spill is real, an extinguishing system may be activated, either manually or automatically. Because the other building systems, such as HVAC, security, lighting, and fume hood controls are not connected to the fire safety system, they continue to operate as they would under normal operation. Fans on fume hoods remain running and certain doors stay locked, exacerbating the situation and compromising the safety of occupants.

NOW CONSIDER THIS SAME ALARM IN A SMART LABORATORY. THE ALARM TRIGGERS AND OCCUPANTS ARE APPRISED OF THE SITUATION VIA VOICE COMMAND, DIGITAL DISPLAYS, TEXT MESSAGE, DESKTOP ALERTS AND/OR OTHER COMMUNICATION MODES TO ENSURE THE EMERGENCY MESSAGE REACHES EVERYONE REGARDLESS OF WHERE THEY ARE IN THE BUILDING OR ON THE CAMPUS.

Escape routes are illuminated and all doors along the route are automatically opened/released.

The extinguishing system is activated, fans shut down, fire dampers are closed, elevators are moved into designated safety positions, and the lab is pressurized to prevent potential chemical exhaust from entering the environment. Emergency response personnel are notified and security cameras in the laboratory automatically focus in on the area where the hazard is present so that facility managers can monitor the situation in real-time. All of these activities take place without human input, allowing personnel to focus their full attention on reaching a safe area as quickly as possible, rather than implementing measures to protect the integrity of the lab.

Total Room Automation (TRA)

Total Room Automation is another critical component of a Smart Laboratory that intelligently combines heating, cooling, ventilation, fume hood control, lighting, and shade control into a single platform to create and automatically assign interfaces that respond dynamically to occupancy. This allows operators to create more efficient, comfortable, and autonomous lab environments by minimizing human touchpoints.

For example, an employee that arrives at the smart laboratory and swipes his/her badge to enter the space. Because TRA can be integrated with the lab's security system, the building automation system (BAS) is "aware" that the lab space is now occupied. Temperature, ventilation, and lighting controls then automatically adjust to the optimal settings for comfortable and safe operations—and only in the spaces where this particular employee needs access.

Similarly, when all occupants have left the lab, the system can automatically adjust light, temperature, and ventilation settings to unoccupied mode, reducing energy consumption and costs while protecting operations. The solution can also adapt to other occupancy settings (modes), such as summer breaks at universities, and short breaks, such as for lunch or meetings.

Occupancy-based operation of the lab can yield significant long-term savings, particularly with regards to airflow and ventilation. Consider a hypothetical laboratory room that requires 12 ACH when it is occupied and/or fumes are present. For the sake of the example, we will assume that the lab is occupied 40 hours out of the week. A conventional laboratory that does not have the ability to detect occupants or air quality would likely have to utilize a strategy where the 12 ACH requirement is met 24 hours per day (unless otherwise adjusted manually by the occupants). This would yield a total of 2,016 air exchanges for the entire week.

Now consider a Smart Lab equipped with advanced sensing technologies to monitor both occupancy and the presence of contaminants (i.e., VOCs, CO_2, particulates, etc.) within the critical environment space.

DURING THE **40** hours where the space is occupied, the ventilation system would provide the required 12 ACH. However, when the room is vacant, the airflow would automatically adjust to 4 ACH. In this scenario, the total number of air changes is **REDUCED BY 50%**

Analytics Services

Organizations require visibility into lab performance in order to ensure personnel safety, compliance with codes and standards, and operational efficiency.

Analytic Services for Labs enables this by transforming raw data into valuable insight so that a systematic, non-intrusive monitoring and preventive maintenance approach can be implemented for critical areas, including lab ventilation and sash management.

Key to the analytics is the delivery of secure, cloud-based dashboards that are integrated with the BAS to help lab personnel visualize equipment and energy performance. In this way, lab managers and building system OEMs can periodically review performance dashboards and reports and identify areas for ongoing improvement. Specifically, lab managers gain transparency, visibility, and guidance for:

- Lab optimization strategies, equipment maintenance, and services that will improve lab performance
- Individual fume hood ventilation, room ventilation, temperature, pressure, and humidity performance over time to identify equipment performance issues, and optimization opportunities
- Sash position on individual fume hoods over time to identify equipment that is not working properly or is not used according to policy, regulations, or safety
- Cost and efficiency impacts to fault occurrences and airflow reductions
- Trend analysis and data retention for safety and compliance management

		Analytics for Labs
Value	Primary	Visibility for safety and compliance
	Secondary	Reduce energy cost when possible
Experience	Common KPIs	Lab/fuel hood airflow, temperature, sash management, cost savings
	Frequency	Monthly analysis and reporting
Deliver	On-site	Service contract
	Cloud	Remote resolution

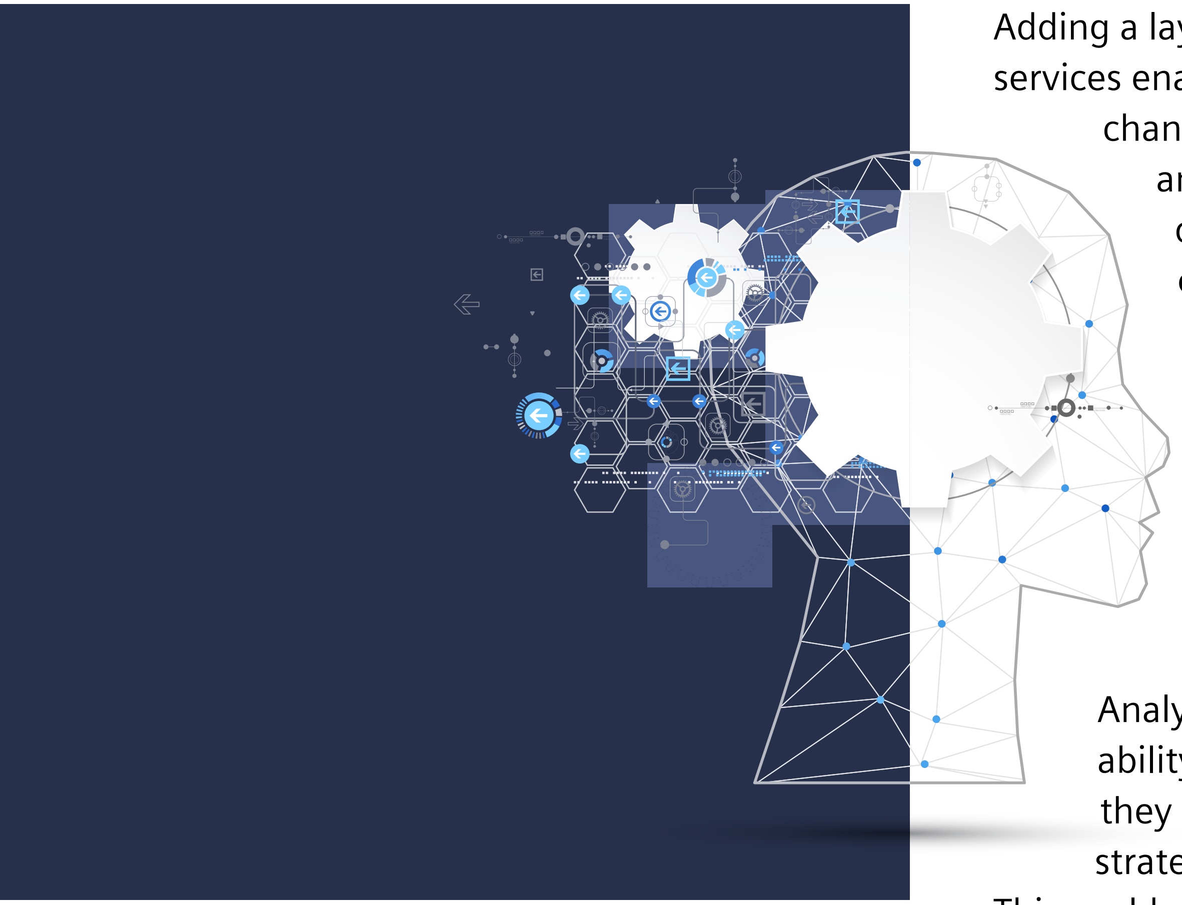
LAB TRANSFORMATION

BEFORE

- Low visibility into lab performance over time for safety/sash management and compliance
- Murky relationships between equipment operation and controlable costs
- Limited ability to proactively manage maintenance and predict problems

AFTER

- 24/7 trending of lab performance and historical data available on-demand
- Time and cost analysis provided for the occurrence of any anomalies
- Fault detection and diagnosis proactively identifies potential failures and root causes



Adding a layer of intelligence with analytics services enables organizations to fundamentally change the way they approach lab design and operation. The focus of laboratory designs in the past has been based on implementing concepts that allow for capabilities, such as daylight harvesting. However, the majority of organizations have never actually implemented the necessary tools to gather data and track the effectiveness of their designs.

Analytics gives lab designers the ability to do exactly that. In this way, they can begin to implement proven strategies backed by real-world data. This could mean altering the physical design or architecture of the lab, for example removing or adding a fume hood based on area occupancy and utilization. It could also apply to operational strategies, such as incorporation of circadian rhythm lighting in designated areas. In both cases, the analytics provide validation to both designers and users that their infrastructure is being operated in a manner that aligns with laboratory objectives.

Next-generation Airflow Control

Intelligent airflow control is one of the technical building blocks of a functional Smart Lab.

AS PREVIOUSLY MENTIONED, APPROXIMATELY 60%

OF ALL LABORATORY ENERGY BILLS GO TO HVAC SYSTEMS THAT NEED TO PROTECT OCCUPANTS FROM AIRBORNE HAZARDS.

Airflow impacts fan power, as well as loads for heating, cooling and humidity control. It is part of several important exposure control measures, including fume hoods, room ventilation and room pressurization. In turn, ventilation systems support the exposure control devices and pressurization strategies that protect lab workers and their colleagues. It is therefore essential that building owners and laboratory managers take the proper steps to optimize airflow.

The GOLO™ Intelligent Air Valve (IAV) from Siemens was designed for this very purpose – providing 100:1 turndown capability to deliver lower-controlled minimum airflows that enable energy savings, while maintaining safe, pressurized environments. The valve is enabled by lower duct velocities and pressure drops.

It is a high precision, low airflow measurement and control terminal unit that uses a dual-blade damper system and advanced algorithms aimed at reducing energy usage.

GOLO™ IAV provides fast-acting, stable and precise lab airflow control over the entire range of room airflow requirements. Utilizing the power of edge computing, sensors can provide the data needed to respond quickly to local environmental needs. It is pre-engineered, factory fabricated and tested to reduce field installation costs, while providing industry-leading air volume measurement and control. Easy to design and install, the solution includes a VAV terminal with reheat, all controls and hydronics preassembled and leak-tested as a complete package.

CHAPTER 4 – Building a Smart Lab: A Process, Not a Project

It is important for lab managers to understand that the process of building a Smart Lab does not happen overnight. Rather it requires an iterative approach where incremental improvements are achieved over time based on user-specific KPIs. The process can broadly be separated into four steps:

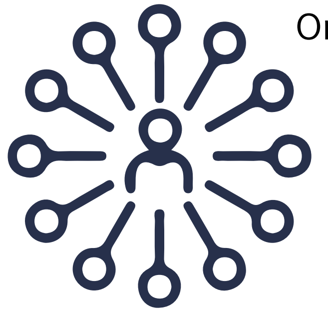
Step 1: Define business objectives and KPIs

As with any continous improvement strategy, defining business objectives and KPIs early on is critical to tracking progress and determining areas of the laboratory where digital tools and technologies should be applied. After all, lab managers cannot manage what they cannot measure. Business objectives should be kept high-level (i.e., reducing utility bills, improving safety, etc.) and associated with at least one KPI that can be tracked, and quantified.

1. Define business objectives and PKIs

Business objectives	Key performers indicators
Attract and retain the best people	Employee/user satisfaction
Meet reduce budgets	Utility bill or meter data
Meet environmental regulations	Exhaust plume emissions
	Public perception survey
	Lab/process productivity

Step 2: Implement infrastructure to connect disparate systems and measure performance



Once KPIs have been identified, organizations can then begin to evaluate their current infrastructure and systems to determine where visibility gaps exist and how best to fill them.

Key to this the deployment of an integrated BMS that connects critical building systems for fire safety, security, ventilation, lighting, power, etc.

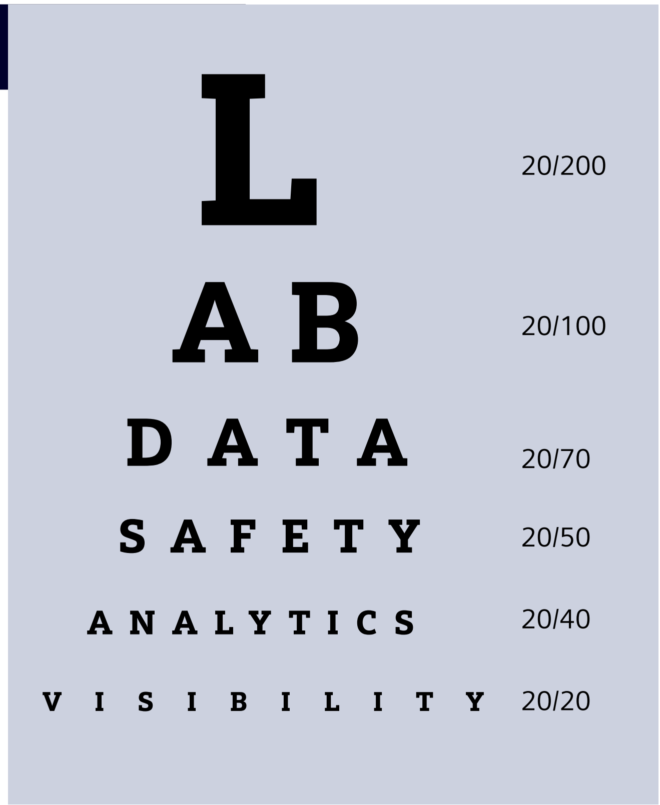
The integrated BMS enables managers to monitor, supervise, optimize and control the entire lab infrastructure from a single interface that can be accessed through an onsite workstation or remotely using mobile device.

During this stage, it can be tempting for organizations to “overcollect” data. However, more data is not always better and it is important for managers to focus only on areas that are relevant to their respective KPIs.

2. Connect systems and colletc data

Data sources

- **Physical assets data (static)**
  - HVAC, security, and life saefty equipment
  - Building characteristics
- **Performance data (dynamic)**
  - Air flow rates
  - Pressure, temperature, humidity
  - Fume hood sash management
  - Indoor environmental parameteres
  - Energy consumption
- **External Data**
  - Weather forecast
  - Compliance data
  - Utility rates

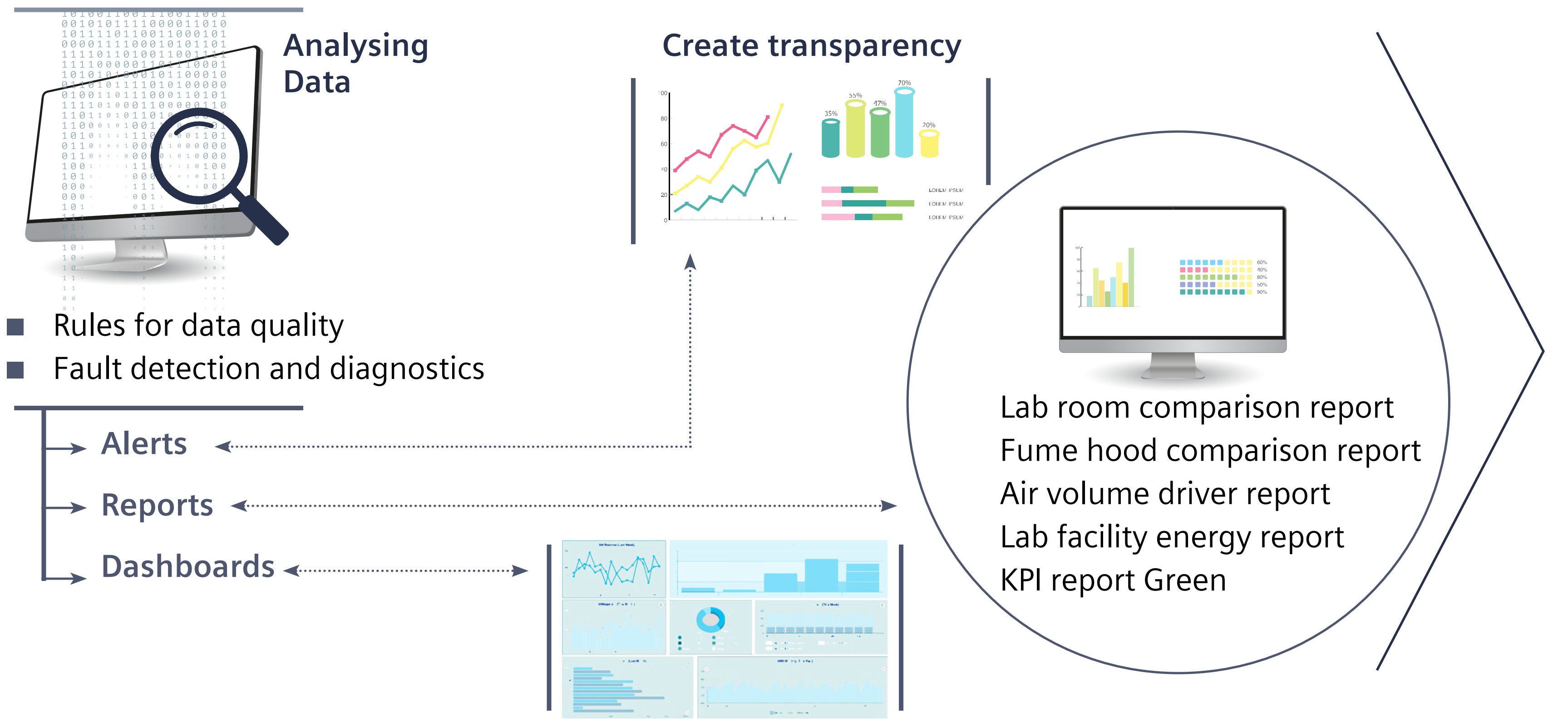


Step 3: Implement a centralized analytics platform

Intelligence is derived from the implementation of a centralized analytics platform that organizes raw data so that users and managers can create meaningful reports and glean actionable insights aimed at optimizing performance with respect to pre-defined KPIs.

The platform integrates services, along with third-party applications, to help lab personnel proactively maintain their lab infrastructure. This is achieved thorough advanced capabilities, such as fault detection and diagnostics, which monitor system operation for abnormal behavior – typically before any alarm is triggered. Lab managers can transform maintenance strategies from reactive to predictive, saving costs on overtime, expedited shipping charges, rental equipment, etc.

3. Implement a centralized analytics platform



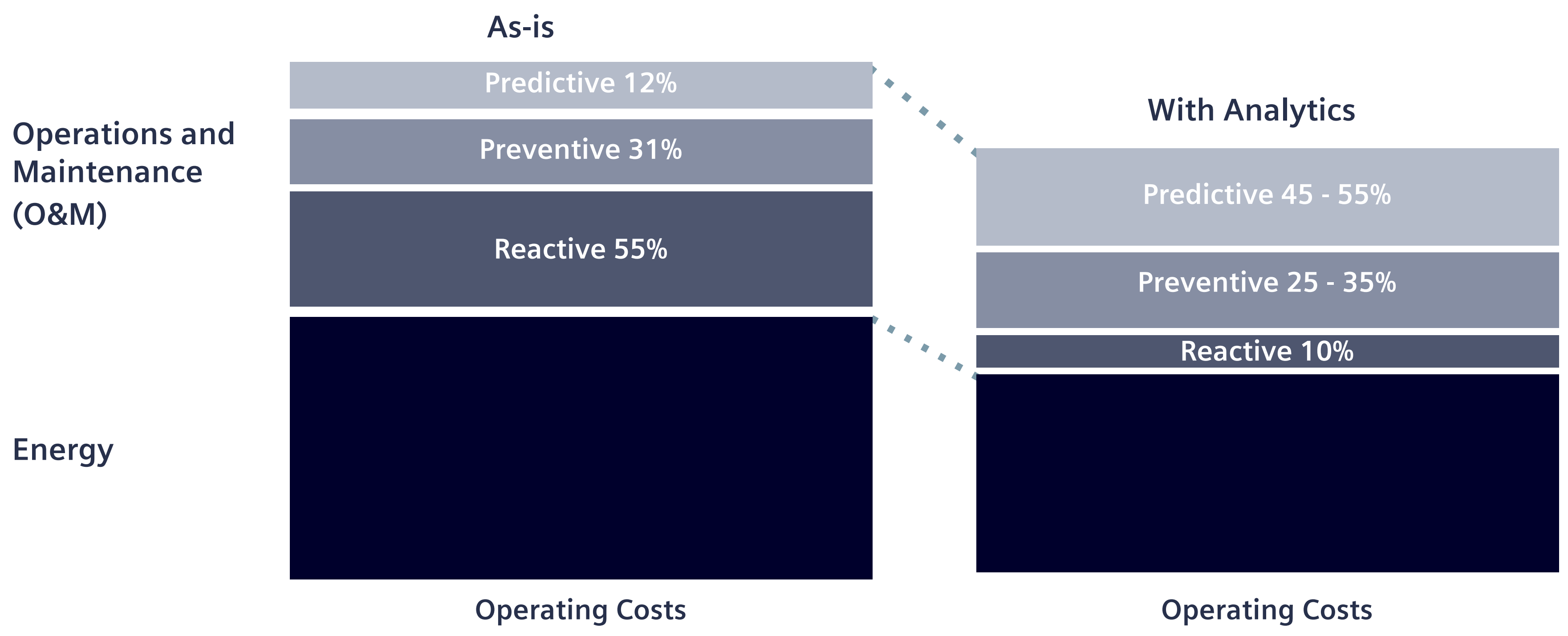
Actionable insights

- Identity inefficiencies through rule-based analytics
- Propose replacement or maintenance of devices and systems
- Propose lab improvement measures

Step 4: Create a system to regularly take action and continually enhance performance

With insights from analytics services, lab managers can begin to take decisive action based on data to continuously enhance the performance, efficiency, and design of their facilities. Because a laboratory's objectives and function evolve over time, this should be ongoing process in which lab stakeholders and building system OEMs conduct periodic reviews of performance dashboards and reports to identify areas for ongoing improvement.

4. Take action and continuously enhance performance



CONCLUSION

The time has come for lab owners and managers to examine traditional designs and operating procedures from a fresh perspective and harness the power of digital transformation and more to begin developing the Smart Lab infrastructure of tomorrow.

As this resource has outlined, by employing an integrated digital approach, laboratories can:

- Provide a safe, secure, and comfortable environment for occupants
- Ensure regulatory compliance and environmental monitoring
- Optimize energy saving and operational efficiency
- Reduce carbon footprint
- Improve lab quality and productivity
- Reduce/predict downtime

Building a Smart Lab and achieving these objectives does not happen overnight. It requires a strategic approach where incremental improvements are realized over time based on user-specific KPIs. Every laboratory is unique in its makeup and objectives, and the transformation process will vary accordingly.

Regardless of the systems you have in place today, Siemens is a trusted advisor and can assist you in the journey. For additional information on how we can help, talk to one of our Life Sciences experts today.

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