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White Paper

A Smart Way to Achieve Smart Buildings:

Delivering intelligence as a service

By James Tu, Social Energy Partners and Joseph Aamidor, Aamidor Consulting

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Introduction

A number of converging technological forces have emerged over the past decades. Most notably, the exponential growth of computing power and the corresponding drop of computing cost, rapid software development, and explosion of the Internet ecosystem have enabled organizations large and small to adopt an expanding universe of diverse technologies. In the built environment, ***intelligent building technologies (IBTs)***, can dramatically improve operating excellence, energy efficiency, human comfort and productivity, and safety and security.

Buildings consume large amounts of energy, account for significant operating costs for organizations, and produce nearly half of the world's greenhouse emissions. Commercial, residential, and industrial buildings are responsible for 47% of global greenhouse gas emissions and 49% of the world's energy consumption, according to Navigant Research's 2015 Global Building Stock Database.[1] And according to the Energy Information Agency, there are over 6 million commercial and industrial buildings in the U.S. alone, and these buildings spend more than $400 billion per year on energy.[2]

Although energy cost is significant for building operations, other non-energy costs far outweigh them. According to a real estate industry rule of thumb from Jones Lang Lasalle, called the "3-30-300™", each year on average it costs a building $3 per square foot in utilities, $30 per square foot in rent and $300 per square foot in payroll.[3] For example, the quantifiable non-energy cost benefits for energy efficiency retrofits alone have been estimated to range from 25-50% of the total benefits of energy efficiency.[4] Hard to quantify benefits, like increased productivity, exceed energy costs savings. How buildings function from energy, intelligence and productivity standpoints are crucial to corporate profitability, overall economic output and the global environment.

However, the facility management and construction industries have been slow to adopt and realize the full benefits of technology. According to KPMG's "Building a Technology Advantage – Global Construction Survey 2016", for the 200-plus senior construction executives who participated in the survey, just 8% of their companies rank as "cutting-edge visionaries", while 64% of contractors and 73% of project owners rank as "industry followers" or "behind the curve" when it comes

[1] https://www.navigantresearch.com/research/global-building-stock-database
[2] https://www.eia.gov/consumption/commercial/
[3] http://www.us.jll.com/united-states/en-us/Documents/Workplace/green-productive-workplace-perspective.pdf
[4] ACEEE, http://www.ase.org/sites/ase.org/files/ase-sei_going_beyond_zero-digital-vf050317.pdf

to technology.[5] No wonder hardware and software technologies, which have dramatically disrupted the status quo and transformed nearly every aspect of daily lives globally over the last 20 years, have not had a similar impact in modern buildings.

While large organizations have inertia that makes change difficult, several factors are exacerbated by the nature of IBTs, including:

- Complex and widely different domains of technology across the building lifecycle that require thorough analysis and evaluation by building owners or tenants
- Fast changing nature of IBTs that trigger risk aversion from building managers
- Uncertain return on investments that depend heavily on rigorous and time consuming measurement and verification (M&V) processes and adoption by building staff or outside service providers
- Need for coordination and collaboration among different departments of an organization, including but not limited to: facility management, corporate sustainability, finance and IT, as opposed to enterprise technologies that are administered solely by the IT department
- Need for new budgets to be created as IBTs are a new category of technologies in buildings.

These barriers have slowed down adoption of IBTs. In this white paper, we discuss a different way to procure and use these valuable, innovative technologies. The “as-a-service” model, which transforms direct IBT purchase and ownership to an ongoing service subscription, brings a breakthrough solution to combat the multiple challenges summarized above. This paper provides perspectives regarding why and how intelligent building technologies “as a service” (IBTaaS) are a change agent to accelerate adoption by organizations worldwide.

The paper begins with a summary of technology and real estate trends that are impacting building owners and operators. Then it defines and explains the concept of intelligent buidling technologies (IBTs). The paper then discusses the value of an “as a service” model and concludes with a summary of the various benefits that are delivered by IBTaaS.

[5] https://home.kpmg.com/xx/en/home/insights/2016/09/global-construction-survey-building-a-technology-advantage.html

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Table of Contents

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Understanding technology trends, their impact on buildings and the future of building management

Why are modern technologies finally revolutionizing building performance? What are the key technology trends and how do they impact buildings? What market drivers will affect real estate at large? How should building owners and operators respond to these accelerating innovations?

Understanding the Internet of Things (IoT)

The internet of things (IoT) is a term that describes the proliferation of IP-addressable hardware enabling physical assets to connect to the internet. Until recently, the internet was reserved for computers, mobile phones and tablets - a communication and data transfer system between these devices and their users. However, IoT indicates that any and all physical things will be "online", leveraging various information technologies including software, electronics, sensors, Internet, broadband connectivity, cloud, artificial intelligence and machine learning. Some novel, consumer facing offerings have started entering the market, such as refrigerators with cameras that enable a grocery shopper to check how much milk he or she has at home. While there will be many of these offerings, there are many other enterprise-focused IoT offerings that could vastly improve and transform various aspects of enterprise operations, including how buildings are managed.

James Manyika and Michael Chui of the McKinsey Global Institute, in a Fortune article,[6] summarize the internet of things as "the use of sensors and other Internet-connected devices to track and control physical objects". They also note that IoT "opens up entirely new ways of doing business". McKinsey research estimates that IoT can reduce maintenance costs by 25 percent, eliminate about 50 percent of unplanned equipment outages, and extend equipment life for years. For any business with physical infrastructure, this is a compelling value proposition.

Expectations are high for the internet of things because while the majority of technology firms today are simply focused on software, the internet of things has the potential to transform all industries in some way. There are a number of ways to quantify the impact that IoT will have on the economy. McKinsey estimates that the total economic impact could be up to $11.1 trillion by 2025.[7] GE, which has started calling itself "the digital industrial company", is even more bullish. It estimates that the industrial internet, which is a subset of the total internet of things opportunity (and focused on enterprise, industrial use cases), will add $10-15 trillion to worldwide GDP by 2020.[8]

These numbers may seem large, but the scale of how connected devices will permeate our economy also is staggering. Cisco estimates that by 2021, over half of all device connections will be machine-to-machine, accounting for nearly 14 billion in total.[9] The other device connections will be what is more common today: computers, smartphones, tablets and televisions. IHS predicts that the number of connected IoT devices will grow from 27 billion in 2017 to 125 billion in 2030.[10]

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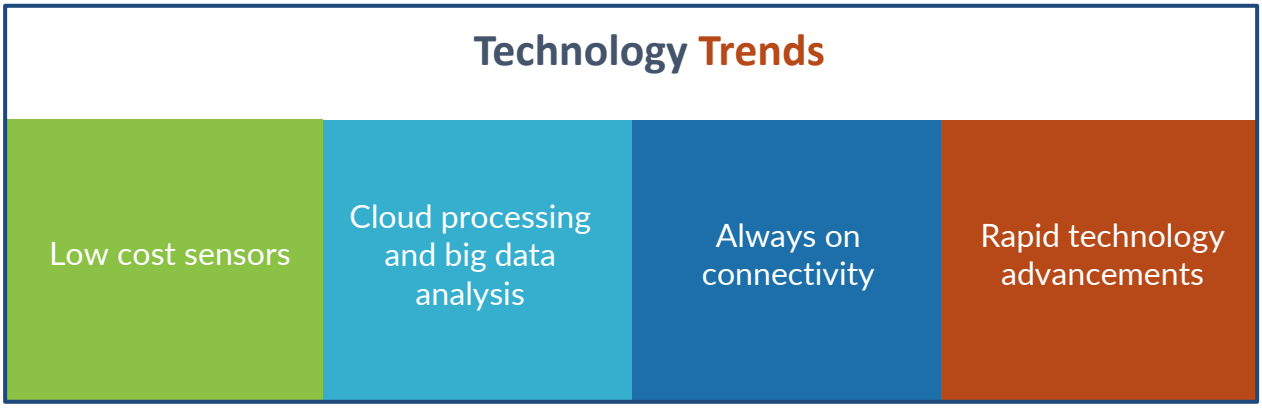
[6] http://fortune.com/2015/07/22/mckinsey-internet-of-things/
[7] https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world
[8] https://www.ge.com/reports/post/76430585563/new-industrial-internet-report-from-ge-finds/
[9] http://www.zdnet.com/article/report-iot-devices-to-dominate-connected-device-landscape-by-2021/
[10] https://cdn.ihs.com/www/pdf/IoT_ebook.pdf

Steve Case, founder and former CEO of America Online, discussed IoT in his book, "The Third Wave". Case notes that there have been three waves of the internet:

- **First Wave:** "Building the internet" which connected homes and businesses to the web for the first time. Companies in this wave include AOL and Cisco, among others.
- **Second Wave:** Once internet connectivity became ubiquitous, in the 2000s apps and mobile experiences enabled firms to differentiate. Search, social and ecommerce firms grew on top of the foundation laid in the first wave. Companies in this wave include Amazon, Google and Facebook.
- **Third Wave:** This wave has just started in the past few years. Case calls it the "internet of everything" (his phrase of choice for IoT). Case notes that "ubiquitous connectivity enables entrepreneurs to transform major, real world sectors".

The Three Waves of the Internet, from "The Third Wave", by Steve Case

Case's book provides a useful framework. When considering the impact that the first two waves had on society, it is easy to understand why IoT is so important and how it will impact various industries.



At the core, there are a number of technology trends that are driving IoT:

- **Low cost sensors:** Sensors of all kinds are starting to be deployed in many places. This includes sensors across farmland that track crop growth to motion and optical sensors in buildings to understand shopping or office utilization patterns. IHS is only one of the research firms that estimates significant growth in proliferation of IoT devices. Zion Market Research forecasts a 24 percent combined annual growth rate (CAGR) from 2017 through 2022.[11] The U.S. Department of Energy in 2015 forecasted that prices for sensors and controls are expected to come down by a factor of 10 in the next decade from lower cost, printed electronic substrates for circuits, sensors, antennas, solar photovoltaics (PVs), and batteries.[12]

- **Cloud processing and big data analytics:** Once data is collected by sensors in the field, software infrastructure must turn these large quantities into actionable information and insights. This is where cloud processing and big data analytics are critical. Without solutions to make sense of the data, operators and other professionals will become overwhelmed. IHS notes that in 2016, the main platforms to enable data analysis, software-as-a-service (SaaS), platform-as-a-service (PaaS), and Infrastructure-as-a-service (IaaS), were worth $54.8B, $10.7B, and $48.2B respectively.[13] As an example of the significant growth in this space, Amazon Web Services (AWS), the market leader, saw 42 percent growth in the third quarter of 2017. AWS made up about 10 percent of all of Amazon's revenue.[14]

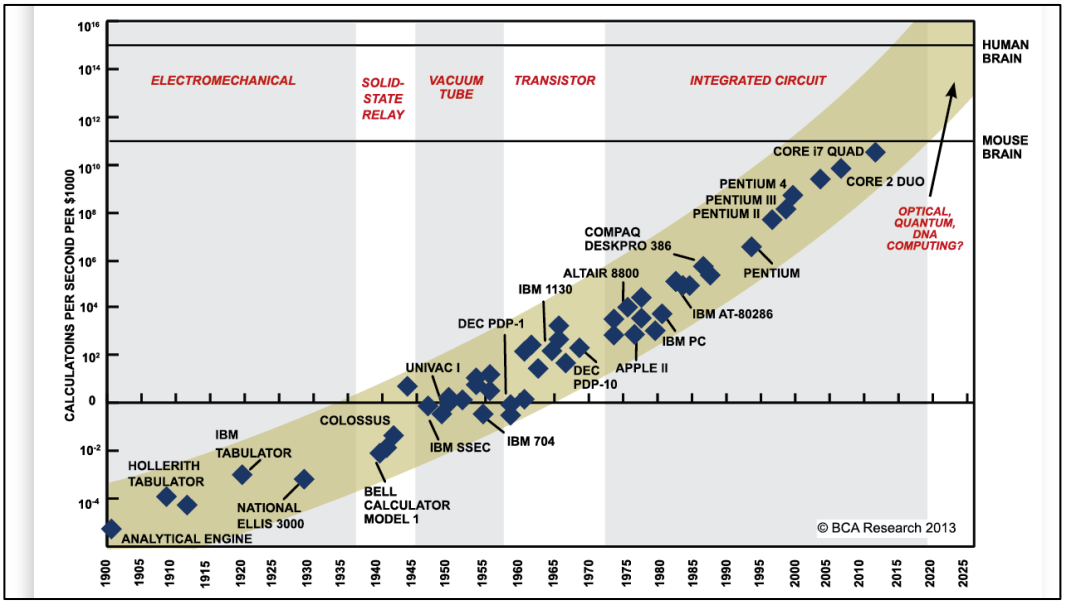
- **"Always on" connectivity:** In addition to sensors being ubiquitous, they will always be connected and reporting new data. This is driven by advanced cellular networks with sensors that have a 10 year battery life. IHS also notes that 5G, which provides less than 1

[11] https://globenewswire.com/news-release/2017/10/30/1159657/0/en/IoT-Sensors-Market-Size-2016-2022-Global-Industry-to-be-Worth-US-27-38-Bn-by-2022.html
[12] http://energy.gov/eere/buildings/downloads/low-cost-wireless-sensors-buildingapplications
[13] https://cdn.ihs.com/www/pdf/IoT_ebook.pdf
[14] https://www.cnbc.com/2017/10/26/aws-earnings-and-revenue-q3-2017.html

millisecond latency, the ability to connect 100,000 devices to a single cell tower, and dropping costs, is one of the key drivers of continuous, reliable connectivity.[15]

- **Rapid technology advancements:** The common driving force among the rapid development of various technologies surrounding and supporting IoT is the continuing exponential growth of computing power following Moore's Law, which projects that the density of transistors in an integrated circuit would double approximately every two years[16]. After nearly six decades since the invention of integrated circuit in late 1950s[17,18], the power of Moore's Law continues to compound, resulting in the ever accelerating foundational technology developments noted above to ensure that new firms with innovative solutions will continue to enter the market in ever greater speed and ever larger numbers. As hardware and software become higher-performing, cheaper and more accessible, more end-use applications will be offered that impact every aspect of modern lives and businesses. Just as Steve Case highlights the fact that the third wave will enable "entrepreneurs to transform major, real world sectors", he sees that technology advancements will accelerate.

Moore's Law: Exponential Growth in Computatoinal Power since 1900, from Ray Kurzweil



[15] https://cdn.ihs.com/www/pdf/IoT_ebook.pdf
[16] https://en.wikipedia.org/wiki/Moore%27s_law https://en.wikipedia.org/wiki/Moore%27s_law
[17] https://www.nobelprize.org/educational/physics/integrated_circuit/history/ https://www.nobelprize.org/educational/physics/integrated_circuit/history/
[18] Ray Kurzweil, the renowned technology futurist and Director of Engineering for Google, proposes that the exponential growth curve of technology development has started since 1900 and machine computational power will exceed the human brain by 2030, a phenomenon coined as "singularity". https://neurobanter.com/tag/singularity/

The impact of IoT on buildings

Intelligent buildings are being and will be enabled by IoT. The growth in sensors and the related drop in price, in addition to the expanding ability to analyze and act on the data, makes it more realistic and impactful to apply IoT in buildings. Many commercial buildings have had networks of sensors to control heating, ventilation and air conditioning (HVAC) for decades, before the internet proliferated. These building automation systems (BAS) collect temperature data by zone or room and report back to a central system, which can modify space temperatures.

The broader IoT trend means that buildings will have much better technology, at a lower price point, that is more compatible with other IoT use cases. These intelligent building technologies (IBTs), working alone as well as in sync, will greatly improve energy efficiency, operating performance and occupant comfort, leading to more desirable buildings at a lower operating cost. Building owners and operators who understand their technology options and consider new business models to adopt faster and utilize better these modern and ever-changing IBTs will be able to deliver significantly better building performance.

The quantitative trends for IoT in buildings also are promising. McKinsey segmented its estimate of IoT economic value by industry. It estimates that the impact of IoT on offices will be between $70B and $150B in 2025.[19] For retail environments, it estimates that IoT will provide between $410B and $1.1T of economic value in 2025. Navigant Research, a research firm focused on energy, buildings and the built environment, estimates that the market for IoT in commercial buildings - a different metric than total economic value created - will grow from $6.3 billion in 2017 to $22.2 billion in 2026.20 Memoori, another analyst firm in the building industry, also covers IoT in commercial buildings and forecasts a 20.7% CAGR over a similar period21. While the estimates from each research firm vary, they all agree that IoT will have a significant impact on buildings - from an increased demand for sensors and data collection equipment, enhanced networking capabilities, to growth in professional services that implement and operate the technology, and more apps that provide end-user experiences based on these new data streams.

[19] https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world
[20] https://www.navigantresearch.com/research/iot-for-intelligent-buildings
[21] https://www.memoori.com/portfolio/internet-things-smart-commercial-buildings-2016-2021/

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Commercial real estate trends

There also are a number of market trends impacting commercial and corporate real estate as well as the property management industry and practice. Commercial real estate investors and corporate real estate owners and managers, which typically are large businesses that happen to own or operate significant real estate, also should be aware of the changing landscape. Key trends in commercial buildings include:

Differentiated offices that serve as talent attractors and innovation enablers. Lord Norman Foster, one of the world's most famous architects who designed Apple's Campus 2, notes that buildings will have to differentiate AND be sustainable in the future. He states:

> "Young people will choose office buildings based on facilities and lifestyle but also on their sustainability credentials. Future generations will be much more demanding and much more questioning in terms of what a potential employer will be doing to tackle climate change. So, I think we will see a shift where creating a good quality working environment which is more responsible in terms of sustainability becomes good for business as well as for the environment ".[22]

Jones Lang Lasalle included "human experience" as one of their 10 office trends for 2017.[23] From the report, "a place of work is more than just a property. It's an environment that can help individuals and businesses achieve their business ambitions ". Similarly, Canadian Property Management magazine notes that over the past 15 years, employees have become a major consideration when it comes to positioning office space. It also notes that human resources departments are now a key stakeholder in the office design and selection process. The article cites a few reasons for this trend, including the "large war for talent" and encouraging employees who might prefer to work at home to instead come into the office.[24]

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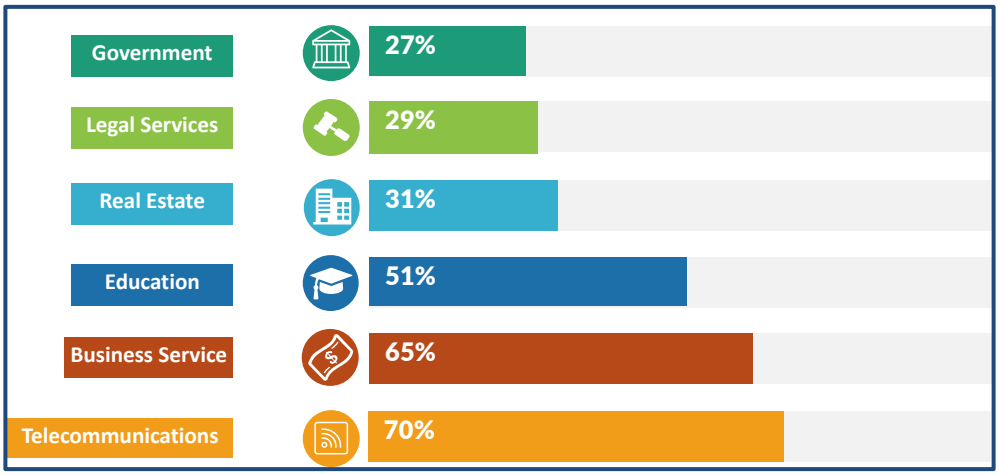
[22] http://www.cnn.com/style/article/what-will-the-office-look-like-in-10-years/index.html
[23] http://www.jll.com/research/global-trends
[24] https://www.reminetwork.com/articles/office-space-differentiator-in-hiring-top-talent/

A recent *Harvard Business Review* article on workspaces highlighted examples of various firms rapidly changing the physical layout of their offices. The authors noted that research suggests "that creating collisions— chance encounters and unplanned interactions between knowledge workers, both inside and outside the organization— improves performance".[25] Similarly, the Jones Lang Lasalle paper on 2017 office trends cited data from Boston Consulting Group, Accenture, and CoreNet Global noting that 63% of companies use shared office space primarily to encourage collaboration.[26] Firms realize that their offices are becoming more important to their business and their employees - and in some cases have chosen to completely change the layout. In some cases, firms are subcontracting out their space to disruptive, emerging vendors. WeWork's "Powered by We" offering, in which a private WeWork-style space is built within a corporation's own office, is seen as a significant growth driver into 2018.[27] Across the board, firms are investing in their buildings and making them more attractive and innovative spaces. Technology will play a key role.

Reduction in square footage per person. The square footage per occupant is a traditional office space utilization metric used throughout the real estate industry. In many cases, more employees are being fit into smaller spaces, but technology and smart design are being used to ensure that the spaces don't feel smaller. CoreNet Global reported that by 2013, the average square footage per employee fell to 150 square feet, from 225 in 2010. The report also cited that many individuals interviewed and surveyed expected the square footage per employee to continue to decline.[28]

Space Utilization by Industry, from CBRE Research & Report[29]

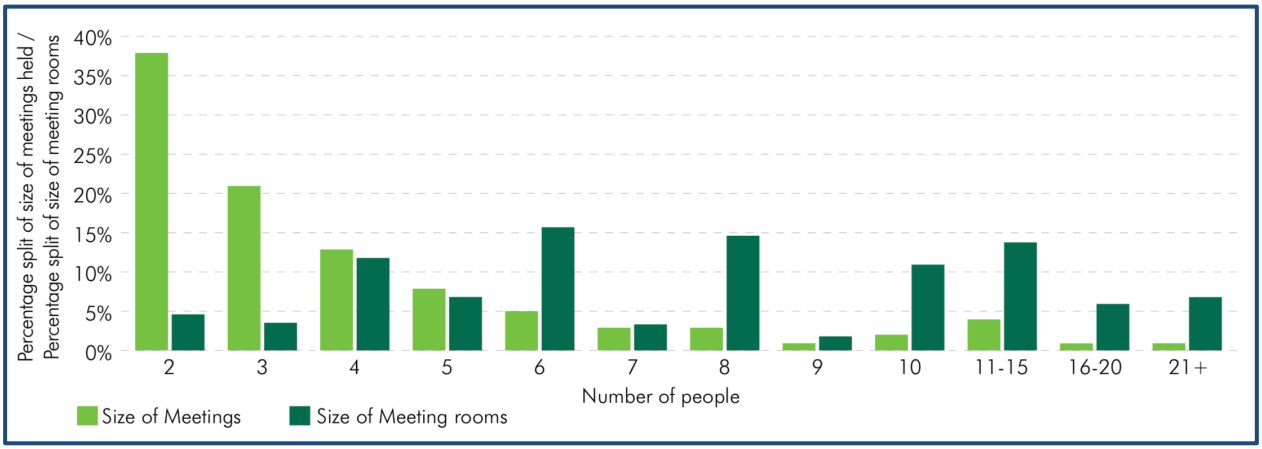


In 2015, facility management firm CBRE published a report on space utilization, noting that globally, offices are typically 40% empty. The US is right at this average, with an office empty rate of 41%.

[25] https://hbr.org/2014/10/workspaces-that-move-people
[26] http://www.jll.com/research/global-trends
[27] http://www.thenewsfunnel.com/real-estate-news/9dG5mbnA2L25vZGUvNzM1MDk09
[28] https://www.bdcnetwork.com/corenet-office-space-worker-shrinks-150-sf

One example provided in the report discusses conference rooms. CBRE finds that while 59% of all meetings involve 2 or 3 people, less than 10% of conference rooms are sized this small. About 30% of conference rooms are sized for 6, 7 or 8 people.[29] Many offices could subdivide larger conference rooms into multiple small rooms to increase utilization. Of course, without better data on how these rooms are used, and when they are occupied, it would be hard to manage such a change.

Meeting Room Supply and Demand, from CBRE Research & Report[29]



The same trend impacts office desk space. The JLL 2017 Trends report similarly finds that 34% of time in an office is spent away from the employee's own workstation. JLL finds that employees instead are in meeting rooms, visiting other employees' workstations, or informally collaborating.[30] Co-working, which enables employees to sit at open but non-assigned spaces, also can increase utilization. But, technology is required to make this scalable and successful more widely. CBRE estimates that per floor (or about 200 employees), the average US firm could save between $300,000 and $350,000 each year by avoiding underutilization of space.[31]

Increased Demand for Green, Energy-Efficient Buildings. Green buildings, which are more environmentally-friendly and energy-efficient have become more common, especially in urban cores. The study, *World Green Building Trends 2016*, conducted by World Green Building Council through a poll with 1,000 building professionals from 69 countries, finds that more than 60% of building projects are expected to be certified green by the end of 2018.[32]
The primary green building certification, Leadership in Energy and Environmental Design (LEED), is administered by the US Green Building Council. Given the significant number of certified green buildings, there is reliable data on how these assets impact the bottom line. A white paper by the

[29] https://www.cbre.com/research-and-reports/apac-space-utilisation-the-next-frontier
[30] http://www.jll.com/research/global-trends
[31] https://www.cbre.com/research-and-reports/apac-space-utilisation-the-next-frontier
[32] http://www.worldgbc.org/news-media/world-green-building-trends-2016

Appraisal Institute and the Institute for Market Transformation cites multiple academic studies finding that LEED and Energy Star, another standard that is run by the US EPA and Department of Energy, have driven rental premiums of up to 25% and 12%, respectively. The white paper also noted that green buildings have significant sale premiums, of between 10% and 25%, and reduced operating costs due primarily to lower utility consumption.[33]

Another research report published by US Department of Energy in May 2017, "Utilizing Commercial Real Estate Owner and Investor Data to Analyze the Financial Performance of Energy Efficient, High-Performance Office Buildings", shows that green buildings realize on average 17.5% lower operating cost and 28.8% higher net operating income versus non-green buildings.[34] Additionally, many cities now require large buildings to report their energy performance annually and some even publish the results and include specific building scores. Many real estate investors see this transparency, especially for under-performing buildings, to be a business risk.

Another standard, the Global Real Estate Sustainability Benchmark (GRESB), enables greater environment, social and governance data to be benchmarked and disseminated throughout the commercial real estate market. In 2017, 850 property companies and funds participated in the annual real estate assessment. Similarly, a new healthy buildings movement, driven by standards like Well and Fitwel, seek to standardize what it means for a building to be a certified "healthy indoor environment". The goal is similar to the green building movement. As more buildings are healthy-certified, it is likely that data on the positive bottom line benefit will emerge. In many cases, making a building greener or more healthy will require an investment in technology - better data and better systems to ensure the building's energy, operating and health performances persist over the lifecycle of the building. Additionally, because these standards are data-driven, better technology reduces the annual reporting burden.

[33] https://www.appraisalinstitute.org/assets/1/7/Green-Building-and-Property-Value.pdf
[34] https://energy.gov/eere/buildings/downloads/utilizing-commercial-real-estate-owner-and-investor-data-analyze-financial

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What is intelligent building technology?

Technology enablers and real estate market drivers are making intelligent buildings a reality. Intelligent building technologies (IBT) are rapidly progressing and networked hardware and software-based systems that improve energy efficiency, operational efficiency and occupant health of a facility and provide "triple-bottom-line" benefits to all the stakeholders: from lowered carbon footprint ("planet"), improved profitability ("profit"), to a better occupant experience ("people"). Intelligent building technologies include solutions to optimize operational efficiency, ensure building safety and security, improve environmental and energy performance, and enhance occupant comfort, health and productivity.

Aligning on a common definition

The term “intelligent building”, like “smart building”, is not new. However, until a few years ago, this term typically referred to buildings with modern building automation systems, but nothing that truly gave the building smarts or intelligence. Now some technologies provide capabilities that remove the need for human oversight and control in some scenarios. There are a variety of examples. A building that can adjust temperature setpoints to reduce energy consumption when curtailment signals are received (known as automated demand response). Or, a building that tracks real-time occupancy to optimize lighting and temperature.

One challenge in the past is that intelligent buildings have been framed solely as a technology solution. The focus has been on technologies rather than outcomes. In the past, vendors have assumed that building owners and operators, as well as real estate investors, will all immediately see value from technology just by implementing it. The bottleneck is not if the technology is effective, but if the organization is able to overcome inertia and risk aversion to adopt new solutions and strategies. Moreover, the capital required to procure technology dissuades some organizations.

Many building operators already are overwhelmed with too much data from a multitude of existing systems. More data, even if it is more accurate or provided in a more usable fashion, is not necessarily a significant benefit to the building. This is because many building operators still are not measured on data-driven goals. For example, operators may be expected to avoid significant equipment outages, but they are provided funds to have a service contractor that will perform regular maintenance and respond quickly to issues. Technology may be a way to reduce the costs and improve the service delivery, but many building operators think the status quo is good enough, or a new way of doing things is too risky. A definition of intelligent buidling technology must include these considerations

A number of organizations have developed their own defnitions. Memoori, a leading research firm in the buildings sector, defines the building internet of things (BIOT) as: “The overlaying of an IP network, connecting all the building services monitoring, analyzing and controlling without the intervention of humans.”[35] This is a technically accurate definition, but does not emphasize the outcomes that can be realized. The American Council for an Energy Efficient Economy (ACEEE), which publishes many reports on the intelligent building space, has a more outcome-focused definition: “Smart buildings use interconnected technologies to provide building owners and occupants with both energy savings and non-energy benefits.“

Considering the rapidly changing nature of intelligent building technologies that effect all stakeholders, our definition is:

[35] https://www.memoori.com/portfolio/internet-things-smart-buildings-2014-2020/

Intelligent building technologies (IBTs) are rapidly progressing and networked hardware and software solutions that can optimize buildings' operational efficiency, improve environmental and energy performance, enhance human comfort, health and productivity and elevate building safety and security for the benefit of building owners, operators and occupants.

What IBT includes

In recent years, IBT typically has referred to either energy management solutions or extensions to tactical and operational building automation systems. But, intelligent building technologies actually are far broader. One unifying theme is that they typically fall into the category of the internet of things (IoT). The various metrics to quantify intelligent building performance include a few categories:

- Energy efficiency: minimize energy consumption and carbon footprint
- Operational efficiency: reduce costs to manage and maintain the building, which includes the physical equipment and the data streams that can be collected and analyzed
- Occupant wellbeing: Hardware, software and services that improve human environment and help occupants perform better, improve their health and wellbeing, and enjoy their time in the space more
- Safety and security: From base requirements like fire detection and suppression, and building access, security and surveillance to emerging needs, such as improved indoor air quality and water

Energy efficiency solutions include energy reduction solutions from software that identifies inefficiencies to equipment such as variable speed drives (VSDs) that reduce energy use to hardware such as LED lighting with rapidly growing efficiency and falling cost per lumen and to integrated controls with sensors and software algorithms that optimize the efficiency of various energy equipment. Historically, many intelligent building technology products were exclusively focused on energy savings (typically called "building energy management systems"). This is because energy is clearer to quantify than some other benefits of intelligent building technology. In addition, energy spending is a significant part of a building's operating expenses and therefore energy efficiency technologies could make impactful reductions on a building's overall operating efficiency. In its 2016 survey, FM Benchmark, a global facility management consulting company, estimated that utilities account for on average 35% of buildings' operating cost, which also includes maintenance (28%), janitorial (19%) and security services (18%)[36].

[36] https://officeinsight.com/officenewswire/fm-benchmarking-office-building-operating-costs-rose-slightly-2016/ https://officeinsight.com/officenewswire/fm-benchmarking-office-building-operating-costs-rose-slightly-2016/

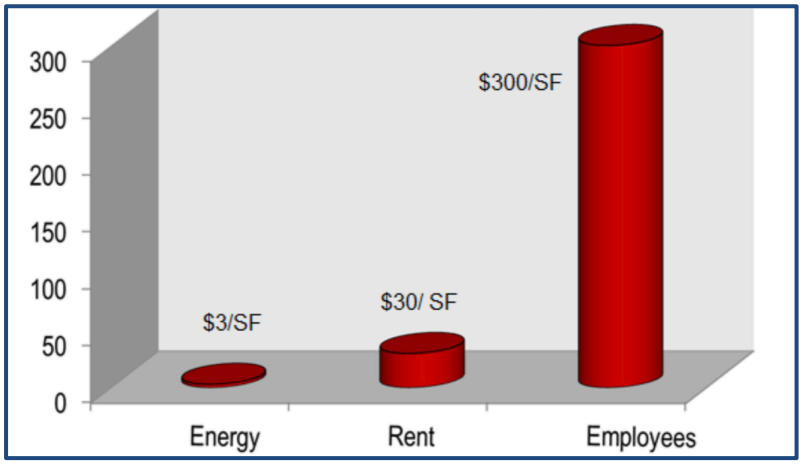
IoT technologies in buildings are now enabling even more advanced operational solutions that can automatically optimize building operations. For example, HVAC optimization solutions will collect a variety of data points about the building's operation and can automatically adjust temperature setpoints to reduce energy consumption and ensure that occupants are comfortable. This solution is compelling because in many cases, acting on hot and cold calls - complaints from occupants about indoor temperature - is one of the biggest time consumers and nuisances of the building and facility operations staff. Additionally, the setpoints in a building may not be set according to local weather or occupant preferences. There are at least a handful of dynamic HVAC optimization systems that could reduce cooling by 20% or more. And while it's not a commercially available product (and it likely would be excessively expensive if it was), Google's DeepMind artificial intelligence solution was used to reduce cooling in a data center by 40%.[37] And, hardware retrofits, like adding LED lighting, continue to be popular because of the compelling ROI.

Behind utilities, maintenance is often the second largest expense in buildings. In the past few years, enabled by IoT trends such as low-cost and easy to deploy sensors and ubiquitous cloud processing, there are IBTs that focus more on diagnosing and even predicting equipment abnormalities. This may include monitoring components of equipment, be it an HVAC system, an elevator, an exhaust fan, a water pump or manufacturing machinery, that notifying operators when maintenance is required. In the past, service technicians would inspect and maintain these systems on a fixed schedule. Now they can do so based on the actual condition of the equipment, thereby minimize equipment repair and replacement cost and extending equipment life by providing timely, data-driven maintenance.

IBTs that focus on occupant wellbeing are also gaining attention in the market. One reason is that the potential benefits of helping occupants be more comfortable and productive are far more significant than measures to reduce energy. JLL's "3-30-300™" refers to the average annual per square foot costs for an average business. While energy typically is $3 per square foot each year for an office, rent will total $30, and personnel costs, if considered as a per-square foot cost, will approximate $300.[38] JLL notes that "a 2% energy efficiency improvement would result in savings of $.06 per square foot but a 2% gain in productivity is worth $6." The formula also means that a 1% productivity gain is far more significant than even a 10% reduction in energy (which is a fairly realistic efficiency target with today's technology options).

[37] https://deepmind.com/blog/deepmind-ai-reduces-google-data-centre-cooling-bill-40/
[38] http://www.us.jll.com/united-states/en-us/Documents/Workplace/green-productive-workplace-perspective.pdf

The Total Cost of Occupancy, from Jones Lang Lasalle



IBTs focused on improving occupant comfort, performance and satisfaction come in a variety of forms, from software applications that enable them to request services, book meeting rooms and workspaces, to personal control of indoor air quality and the overall environment. Some solutions are hardware based, such as personal comfort systems, which are heaters and/or fans that can be installed at a desk. More modern solutions that control the existing HVAC system on a more localized and real-time basis, which obviates the need for a supplemental personal comfort system, may provide the same outcome to occupants. Connecting these solutions to real estate industry trends noted earlier in the white paper, building owners and operators see technologys to enhance occupant wellbeing as a way to encourage their employees to come into the office more regularly (instead of working at home) and collaborate more effectively with their colleagues.

Safety and security focused solutions are commonly employed by owners and operators. Fire suppression and notification solutions are required by building codes. Access control and security solutions also are considered de facto requirements for many companies, especially those that must protect client information or their own intellectual property. Moreover, many of the required and de facto security solutions can be improved with IoT capabilities. Indoor occupancy monitoring solutions can be used in the event of a fire or other emergency to identify the location of individuals that may need help. Or, this technology can supplement data already collected by access control systems to ensure indoor security.

IBTs in these categories encompass a wide range of hardware, software, cloud computing and service offerings. In many cases, an individual building's goals and needs may not align with a specific vendor's offering. Instead, a combination of offerings from multiple vendors may be required. However, this may require the services of a systems integrator to enable the products to work together, which is not always a simple and cost-effective task. Building owners and facility managers should focus on how the technology will achieve desired outcomes. In some cases, a less

robust technology may be easier to install or easier to use, and lead to bigger benefits and higher return on investments. Additionally, where the building is in its life-cycle also has an impact on how it can benefit from IoT.

A recent white paper from Avison Young, a commercial real estate services firm, notes that a newly constructed LEED Platinum building in Toronto integrated all of its operational systems to a single, wireless-enabled system. Many existing buildings have dedicated, existing networks for each operational system: HVAC, security, power, access control, fire safety, elevators, among others. By combining these systems into a single IP network, the building saved 30% on its installation costs and believes that it will realize energy savings of 30% to 70%.[39] It's also likely that operating the building on a day-to-day basis will be less complex and time-consuming for the facilities staff. This lower total cost of ownership (TCO) will benefit all parties for years to come. However, due to the significant, upfront retrofit costs and disruptions to occupants, this integrated IBT option may not yet be as compelling for an existing, occupied property. Additionally, it is likely that future technologies will provide novel and more cost-effective approaches to more effectively integrate and synchronize the performance of various building systems, including IBTs. Integration of systems within buildings will become easier, not harder, in years to come.

The IBT landscape is rapidly changing, evolving and consolidating. The key challenge to building owners and operators is to benefit from compelling technology while avoiding some of the risks that come with adopting it: technology risks, budget risks due to large capital expenditures, financial risks due to uncertain or unquantifiable return on investment, and user adoption risks rising from organizational resistance to embrace and utilize the technologies. This is a topic that will be discussed in our next section.

[39] http://blog.avisonyoung.com/2016/07/technological-disruption-and-real.html

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Why as-a-service is the right model of IBT adoption

Intelligent building technology is capital-intensive, rapidly maturing, and can be challenging to integrate and operate effectively. An "as-a-service" model eliminates the upfront capital cost, minimizes users' technology performance and investment return risk, reduces the likelihood of technology obsolescence, and is outcome-driven to ensure the solution delivers the expected value.

How does an "as a service" subscription model work?

Across the information technology marketplace, "as-a-service" models have proliferated. Initially software-as-a-service (SaaS) offerings replaced on-premise software that required an organization to maintain its own servers, conduct time consuming and disruptive software upgrades, and get locked in to working with the same vendors over a long period of time. Salesforce, the leading customer relationship management (CRM) software provider, was one of the first firms to embrace SaaS, competing against and ultimately beating on-premise CRM vendors. When they first launched, the company embraced a "not software" brand and slogan to differentiate their "as a service" model. Marc Benioff, the founder and CEO of Salesforce, noted that the company's goal was to differentiate from the rest of the software industry, which was "obsolete and ill-suited for its task ".[40]

Gartner describes software-as-a-service (SaaS) as:

> *"Software that is owned, delivered and managed remotely by one or more providers. The provider delivers software based on one set of common code and data definitions that is consumed in a one-to-many model by all contracted customers at anytime on a pay-for-use basis or as a subscription based on use metrics."*[41]

There are a variety of benefits to such a model, from lower upfront costs, higher user adoption rates and painless upgrades. Applying this "as a service" model to IBTs, it is clear that many of the same benefits apply. Upfront capital for IBTs, especially when significant hardware and greater dollar amount investment is required, may be hard to secure. IBT projects also could be competing against other potentially more mission-critical initiatives that have greater visibility and higher familiarity among key decision-makers in the business. Moreover, due to the rapidly maturing state of IBTs, upgrades in the future may be considered a key risk factor: why invest heavily in technology today when it likely will be even more advanced tomorrow? By implementing IBTs with an "outcome-focused" arrangement, the lead vendor or integrator helps install the solutions and ensures that value is realized. Having such arrangement improves user adoption across the organization because building and facility staff are supported by trained intelligent building technology experts. These topics will be further investigated in the next section.

There is another emerging "as-a-service" model that is worth considering. Some of the recent developments in automobile transportation exemplify a model that could be employed in buildings. While it has been common to own a car for decades, a multitude of other mobility options are now making ownership less critical. Car sharing services, from Uber and Lyft to short-term rental options have enabled people to get all the value of owning a car, which provides more flexibility than public

[40] https://www.salesforce.com/blog/2013/07/marc-benioff-logo-brand-advice.html
[41] https://www.gartner.com/it-glossary/software-as-a-service-saas/

transit, without many of the costs of owning a car (finance charges for the car, insurance, gas, parking). A recent Goldman Sachs report on the future of mobility notes that various car sharing services have much higher utilization rates than privately owned cars. While a personally owned car may only be driven for a few hours a day, a car sharing service vehicle could be used for many hours, transporting different individuals around a region.[42] This changes the business model and also enables firms to profit by benefiting from enhanced utilization.

Intelligent building technologies, delivered in an as a service approach, could provide similar benefits to building owners and operators. For example, instead of each building hiring a full-time expert energy engineer, which would have hard time catching up with the evolutions of various hardware and software solutions deployed throughout a portfolio, a subscription model would enable many buildings to benefit from such expertise at a lower price point. Additionally, the buildings would gain a broader depth of experience than they could hire or employ on their own. Since many buildings do not have the budget to hire an energy engineer, a subscrpition model gives them the benefits - lower energy costs, reduced carbon emissions, improved sustainability posture - at a more appealing price point.

Issues with direct ownership of intelligent building technologies

The benefits of "software as a service" should resonate with building owners and operators who want to adopt IBTs but are looking for a more compelling implementation model. In this section we provide a discussion of the key challenges presented by direct purchase and ownership of intelligent building technologies and how a subscription model avoids them.

IBTs are rapidly evolving and maturing, which renders long-term ownership obsolete. Because of the rapidly advancing state of the internet of things, building owners and operators can benefit from rapidly advancing facilities. On the one hand, this is an enviable position because undoubtedly more and more applicable technologies will be available in the future and likely will drop in price. On the other, given the long retrofit lifecycle of most buildings and the cost conscientiousness of many building managers (that tend to have relatively fixed operating budgets year over year), building managers do not want to continue spending money to upgrade technologies repeatedly as they mature. In fact, due to tight cost controls, coming up with a budget for a new technology in a single year is already a cumbersome and challenging process for most buildings. Therefore, when the decision is to either wait on procuring technology or buying solutions with the expectation that they'll need to be upgraded regularly, most will wait.

42 https://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Rethinking%20Mobility_GoldmanSachsMay2017.pdf

- ***IBT Benefit:*** *Instead of directly purchasing IBTs, an "as a service" model ensures that the building owner/operators are paying for the outcome - energy savings, operational efficiency, improved productivity and enhanced security - regardless of what specific technology and vendor is used to achieve the outcome.*

Technology risk from discerning between offerings and vendors and deciding what to buy. The IBT vendor landscape is complex, rapidly changing and immature. Different types of technology and industrial vendors are competing for market share, including HVAC and building controls OEMs, facility management firms, technology vendors and a variety of startups and other building technology innovators. While analyst firms generally identify a dozen or so leading vendors[43], in fact there are a few hundred firms, large and small, that are offering intelligent buildings solutions. For example, as of January 2018, there are more than 4,700 companies with IoT in their business descriptions, and 1,500 energy-labeled startup companies (founded after January 1, 2012) alone in Crunchbase, a technology business directory. Building managers are confronted with an expanding array of innovative technologies that may not provide clear benefits. Contrast this with the deep knowledge that many building managers have of industrial-age mechanical and electrical equipment. Many IBTs come with short histories of successful implementations that have delivered proven, quantifiable benefits.

In addition, it's likely that some of these firms will be acquired or fail in the coming years. Given the rapid technology changes and what is seen by many as an industry ripe for disruption, other new innovators will assuredly enter the market. Many building owners and operators see this "vendor churn" as a procurement risk. More specifically, going through a procurement process to select an intelligent building vendor may take 9 to 12 months, from initial scoping of the building's needs, collecting information on a variety of vendors to prepare a shortlist, and then running a request for proposals (RFP) process and negotiating with the selected vendor. In this time period, new vendors may enter the market or existing ones might launch new offerings. This creates a vicious cycle in which the technology and offerings in the market move faster than the building decision-makers. Many building and portfolio-owners have simply decided to wait for market consolidation before procuring IBTs.

Moreover, unlike other procurements, technology alone may not be compelling to building owners and operators. In more traditional industrial equipment or technology procurement processes, the technology alone has direct benefits to the business. For example, an updated version of a key business application may directly improve user engagement, reduce platform maintenance costs, and/or provide new mission-critical features that improve top-line performance. IBTs are different because they must be coupled with a persistent training and support program to ensure that they are being used effectively. Additionally, organizations may need to rethink, reorient or reorganize

[43] https://www.greentechmedia.com/articles/read/what-building-professionals-can-teach-us-about-the-way-forward-in-the-smart#gs.mQdV1ns

how they operate their facilities. Unlike other enterprise-grade technology, IBTs are transformational to the business, especially to the building, facility and property management teams.

- ***IBT Benefit:*** *An as-a-service model avoids these technology and vendor risks by selling outcomes. Instead of buying a technology based on novel features, building owners and operators can instead enter into a subscription that provides estimable and quantifiable outcomes at a compelling price point. The as-a-service model also provides an infinite return on investment due to zero upfront cost when benefits exceed subscription costs. The selection of individual technologies or technology vendors is a secondary issue and not the responsibility of the building owner and operators.*

Budget approval for intelligent building technology procurement. In many cases, procuring IBTs requires stakeholders and champions to navigate internal budget processes and compete against other projects for funding. In some cases, these processes are new to facility and building professionals because their budgets include operating expenses that are static from year to year. Intelligent building technology investments may compete against other capital projects or projects across the enterprise. Additionally, there may be internal debate over which team, Facilties or IT, should oversee these solutions, which can delay procurement. Moreover, facility and real estate budgets generally are not increasing, which puts greater pressure on those stakeholders who want to invest in new technologies. Verdantix, a leading analyst firm in the building space, conducted a survey of facility, energy and real estate directors and found that budgets for 2018 will increase just 2.5%.[44] The findings indicate that about a third of the survey participants will increase their spending on software and between 17% and 27% of the participants are trialing or assessing IoT platforms. Between a small overall budget increase and a minority of building owners procuring advanced technology, it's likely that budget approval issues are a barrier to IBT adoption.

On a related note, the costs and benefits of IBTs may be opaque or dependent on building-specific factors. A recent Lawrence Berkeley National Lab (LBNL) report noted that a key barrier to smart building technology revolved around the costs. The report states that "limited information available on full costs and savings potential hinders the business case for implementing an EMIS."[45] [46] There is some data on the potential savings range of some intelligent building technologies. However, it typically is generalized. Depending on type of building, knowledge level of building and real estate professionals, and general priority given to intelligent buildings, the cost savings results will vary

[44] http://www.verdantix.com/newsroom/press-releases/verdantix-survey-finds-huge-variation-in-worldwide-real-estate-energy-facilities-budgets-for-2018-and-reveals-new-trends-in-technology-preferences
[45] https://drive.google.com/file/d/0BzgPTwDtt6KdWnFPX1FWbFQ3TkU/view
[46] EMIS stands for energy management information system, which is a predecessor solution and type of intelligent building technology.

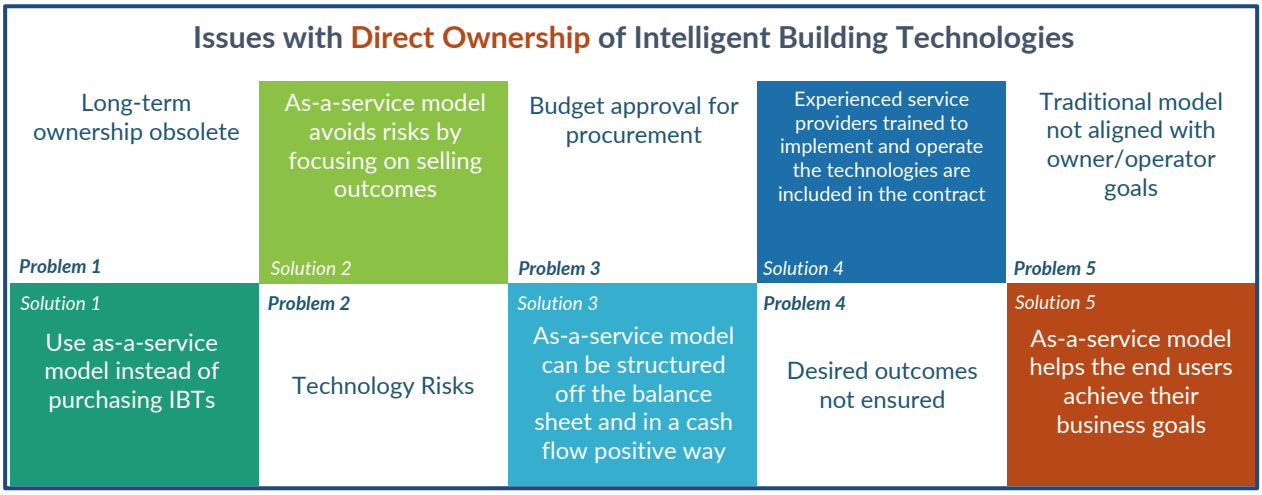
widely. This makes it more difficult to build a compelling and reliable business case to request funding internally.

- ***IBT Benefit:*** *Because IBTs do generate cash by reducing energy and operating costs, a subscription "as a service" model can be structured off the balance sheet and in a cash flow positive way. When several IBTs are bundled in a packaged solution, those with less quantifiable yet significant long-term impacts (that could meet considerable buyer resistence when sold alone) are balanced and funded by those that offer more quantifiable and immediate energy and operating savings. Additionally, working with experienced service providers that provide total solutions, from building audit and technology installation to training and ongoing maintenance, ensures that the building will realize the full value of the technologies.*

Ensuring the desired outcomes are achieved; installing, maintaining and operating new technology. Adoption risk is common with many new technologies. This is especially true with IBTs. Specifically, IBTs typically require routine processes to be rethought and redesigned, a process that can be time and resource intensive. For example, many building engineers perform scheduled checks and walkthroughs of critical HVAC equipment. Data analytics solutions can monitor this equipment and reduce or remove the need for scheduled checks. Instead, technology can identify issues based on real-world conditions, directing building staff to address issues as they are observed. (In some cases, predictive analytics can be used to alert building operators of issues before they occur.) This shift has significant value to all building stakeholders but it requires staff to monitor and react to new systems. It also requires them to trust the technologies. In some cases, building technicians still perform scheduled walkthroughs just in case there is an issue that isn't caught. In other cases, the training and setup steps are arduous and building owners and operators do not dedicate enough time to adequately prepare their staff for new technology solutions. A lack of time may persist through implementation and operation of the technology, reducing the likelihood that the project goals are achieved. The same LBNL report noted that one of the three biggest barriers to technology implementations is a "lack of staff time to review the EMIS dashboards and reports, and to investigate and implement findings." A related problem the report identified is technical integration between existing and new technologies, a challenge that also fits into this category.[47]

- ***IBT Benefit:*** *IBTs are difficult to adopt because they require processes to be rethought, staff to be retrained, and time to be dedicated to their use. An "as a service" implementation model resolves these forms of adoption risk by including in the contract a team of experienced service providers, trained to implement and operate the technology. The outcome-driven model also ensures that building owners and operators will have help each step of the way to ensure they are trained and realize the full value of their procurements.*

[47] https://drive.google.com/file/d/0BzgPTwDtt6KdWnFPX1FWbFQ3TkU/view



Traditional building technology sales model does not align with building owner/operator goals. Most building technology vendors price their offerings in a standard way that is not outcome-driven. Hardware solutions typically are priced by unit and may have supplemental setup, commissioning or maintenance costs. Software typically is sold on a per building or per user license, which may include tiers that offer more features at a higher price point. None of these sales models consider the actual benefits that are realized by the building owner. An enterprise could procure an IBT, have a poor implementation experience from the vendor and receive limited training. They may see limited benefits from the purchase, but they still must pay the same fees. Moreover, the vendors that offer these pricing models are not incentivized to help reduce overall building operation costs. In fact, in a survey[48] conducted by GreenBiz Group with 236 energy and sustainability professionals representing diverse range of companies with annual revenues from $100 million to $10 billion, 46% of the respondents cited "ROIs not attractive" as an obstacle to adopt sustainabilty initiatives. This misalignment between vendors and building owners/operators can reduce the effectiveness of IBTs.

- ***IBT Benefit:*** *An "as a service" model ensures that the solution provider helps the end users achieve their business goals because the offering is funded by the realized savings and benefits. While this model ensures that the building owners and operators achieve their goals, it also helps the solution providers by creating a dedicated revenue stream to fund their work developing or obtaining more powerful IBTs.*

[48] "The State of Corporate Energy and Sustainability Programs 2018", *GreenBiz Group*, February 2018.

IBT-as-a-Service is a financial innovation needed to expedite IBT adoption

In her groundbreaking socioeconomic book, “Technological Revolutions and Financial Capital”, Carlota Perez lays out five historically significant technology revolutions over the past three hundred years:

- the industrial revolution, circa 1771
- the age of steam and railways, circa 1829
- the age of steel, electricity and heavy engineering, circa 1875
- the age of oil, automobile and mass production, circa 1908
- the age of information and telecommunications, circa 1971

Each revolution, without exception, was brought on and proliferated by radical entrepreneurship and idle capital from the exhaustion of the previous paradigm. In each revolution there was a turning point catalyzed by financial innovations, which propelled the technological revolution from an initial installation period to widespread growth that made the revolution the universal fabric of the whole economy.

The ongoing, albeit nascent energy revolution that aims to drastically reduce and eventually eliminate global carbon emissions is a perfect modern-day example. The fossil fuel-based economy that pursued maximum power and production without considering the externality cost from climate change and environmental degradation is now being replaced by renewable power and energy efficiency technologies. In the case of renewable energy, typically solar- or wind- based, the power purchase agreement (PPA) is a financial arrangement for a third-party developer to own, operate and maintain a power system. The host customer avoids the need for upfront capital and has no system performance risk. This served as the financial innovation that contributed to renewable energy’s wider adoption and unlocked an overwhelming majority of market potential that otherwise would be inaccessible due to long payback periods.

The as-a-service model provides a similar mechanism to unlock the potential of IBTs. Industrial companies that have dominated the building space and moved slowly over the past decades are being challenged by IBTs from startup companies that blend and synergize various rapidly changing technologies including hardware, software, Internet, cloud, AI and machine learning into internet of things products and services. Like the companies in the passing technology revolutions, the industrial-age companies today often have too much existing infrastructure, large bureaucracies, and distribution channels to protect. This prevents them from developing or accepting radical technological and business model innovations necessary to succeed in this new IoT age. As-a-service model, by removing capital requirements, technological risk and maintenance cost from customers, has the characteristics and elements of a financial innovation that could accelerate the adoption of IBTs.

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Outcomes enabled with an as-a-service delivery model for intelligent building technology

By avoiding direct purchase of IBTs and enabling a monthly subscription model, a number of outcomes are realized in both the near- and long-term.

The importance of achieving business-critical outcomes

IBTs improve building performance, but in many cases, they are implemented by organizations that are not in the real estate and buildings business. Outside of institutional commercial real estate firms, most building owners and operators participate in other industries, from retail and restaurants, to professional services, education, healthcare, or many others, in addition to government and nonprofit organizations. For these businesses and organizations, it is vital to connect the use of IBTs with business-critical outcomes. Moreover, as mentioned above, the institutional owners or operators may have limited budgets or resources to fully embrace intelligent building technologies. In either case, outcome-driven solution providers can align intelligent building technology capabilities with core business-critical concerns. These building owners and operators will benefit from the subject matter expertise that is provided in an as a service offering.

In many cases, these desired outcomes include more than just energy consumption reductions. ACEEE, in a recent report on the nonenergy benefits of building technologies, notes that "rather than trying to justify an investment based on energy cost savings alone, we can add the value of other benefits into the equation to make a project more appealing."[49] This line of reasoning can be flipped around, too. By procuring IBTs in a "as a service" model, where the energy savings funds the implementation, building owners and operators are likely to get many other nonenergy benefits, too. It is these additional benefits that may be more business critical. For example, the report highlights a variety of "participant benefits", which include the building owners, operators and occupants:

- Improved indoor air quality (IAQ)
- Comfort, health, and safety
- Labor and time savings and increased productivity
- Reduced operating costs and extended equipment life
- Improved process control
- Increased amenity or convenience
- Water savings, water quality improvement and wastewater reduction
- Increased asset value

There also are societal benefits, which may have a positive impact on the enterprise's brand. The report highlights the following societal benefits of intelligent building technologies:

- Reduced pollution and environmental externalities
- Health-care cost savings
- Improved educational outcomes
- Reduced depletion of limited energy resources
- Productivity enhancement
- Economic competitiveness

[49] http://aceee.org/research-report/ie1702

Near-term benefits of intelligent building technologies

After deploying and using intelligent building technologies, building owners and operators will realize a number of benefits. Even in the near term, there are a number of significant business-critical benefits, including:

- **Increased net operating income (NOI).** A key metric to any real estate firm, NOI can be impacted by an increase in revenue or a reduction in costs. In many cases, the reductions in cost, driven by energy or operational efficiency, will occur before the increases in revenue. But regardless, IBTs lead to a compelling increase in NOI. (Similarly, see the next section for a discussion on increased space utilization and how it enables new revenue models.)
- **Increased occupancy and property value.** As noted earlier in the paper, there are reliable data showing that improved Energy Star scores and LEED certification lead to increases in property value and higher occupancy. For now, most data has looked only at the relationship between energy efficiency and property value. However, WiredScore provides certifications of internet connectivity in buildings, finding that tenants will pay more for superior connectivity.[50] This rent premium also drives property value, and such a certification could be extended to other metrics in the future. There are other initiatives that seek to quantify the benefits of intelligent building technology on property value. One initiative in Europe, the Smart Readiness Indicator for Buildings, seeks to recognize buildings with advanced technology as a means to help quantify their incremental value.[51]
- **Improved occupant productivity.** There is an emerging body of evidence that green, high performance buildings can improve worker health, which also improves productivity. The 3-30-300™ rule from JLL is a reminder that any benefit to the occupant is far more financially beneficial than focusing on energy or the building. A group of researchers looked at cognitive function of occupants in high performance buildings, finding that they scored 26.4% higher on cognitive tests.[52] Moreover, another study looked at health and productivity benefits of green buildings. The study by the World Green Building Council cited a number of examples, including a call center in Pennsylvania that saw a 97% jump in sales-generated leads once they moved to a new green building. Additionally, a health insurer in Australia recorded an 80% jump in employee collaboration after their move to a new green office.[53] While the anecdotal evidence is compelling in the aggregate, it still is difficult to measure and estimate the productivity gains which are subject to various other factors such as interference by other environmental or organizational forces as well as personnel changes. As more IBTs are implemented in more buildings, impacts on

[50] https://wiredscore.com/en/
[51] https://smartreadinessindicator.eu
[52] https://www.sciencedirect.com/science/article/pii/S0360132316304723
[53] http://www.worldgbc.org/news-media/building-business-case-health-wellbeing-and-productivity-green-offices

productivity would be augmented, rendering such survey and research more rigorous and statistically significant.

- **Achieving sustainability goals in time.** Industrial equipment for buildings such as HVAC and water heaters, or onsite power generation capacities, be it solar, wind or natural gas, usually require lengthy site assessment, permit, financing and installation procedures. In contrast, IBTs, similar to corporate IT systems, could be implemented quickly, often without the need of permitting. Therefore, IBTs that facilitate energy efficiency improvement could help organizations attain aggressive carbon emission reduction and sustainability goals in a much more timely fashion. As an example, there are several chiller efficiency optimization systems with smart thermostats, sensors, artificial intelligence and machine learning algorithms today that could reduce chiller energy consumption by 20-40% within a few short weeks of project initiation.
- **Attract better tenants.** Earlier sections of this paper establish that buildings with more technology to foster innovation and interaction are viewed favorably by organizations and their employees. Such investments in the physical office space are a response to the war for talent. There is a similar driver for commercial real estate owners and investors: by providing space that meets these emerging needs of potential tenants, the demand for the space will increase.
- **Proactive, condition-based maintenance.** Focusing on the operation of a building's physical systems, IBTs enable facility managers to maintain equipment based on condition, rather than the last time an inspection occurred. For facility managers and technicians with too many tasks and not enough time to complete them, being able to reduce scheduled tasks and use real-time data to plan out their workload can be a significant improvement - both in terms of productivity and overall job satisfaction.

Long-term benefits of intelligent building technologies

As IBTs are deployed and used throughout building portfolios, there are likely to be other benefits realized in the long term. Like many technology innovations, it takes time to understand how best to utilize these advancements. One of the best examples of this is from "The Second Machine Age", by Andrew McAfee and Eric Brynjolffson. The authors first discuss the first machine age, the industrial revolution, driven by steam engines and other advancements. It draws some parallels between technology adoption in that time and in the present day. The authors note that when factories electrified - replacing steam engines with electric motors - they typically saw little improvement in productivity. From the book:

> *"Only after thirty years-long enough for the original manager to retire and be replaced by a new generation-did factory layouts change. The new factories looked much like those we see today: a single story spread out over an acre or more. Instead of a single massive engine, each piece of equipment had its own small electric motor. Instead of putting the machines needing the most*

power closest to the power source, the layout was based on a simple and powerful new principle: the natural workflow of materials."[54]

The point is that it took decades for processes to change to enable new technology to deliver performance improvements. While there are direct, near-term benefits of IBTs, it's likely that other value streams will emerge in years to come. Some of those benefits include:

Higher space utilization and new business models. To the extent that property owners can reduce the per-occupant square footage and increase the number of on demand tenants, they will find that they can generate solid returns. Indoor sensors to monitor utilization can provide data that quantifies office use and informs renovations and other modifications. This indoor sensing data also can be used to help employees find available workstations, which in some cases may be underutilized. As such technologies are adopted more widely, it will enable growth in on-demand office space. Tenants, instead of entering into a multi-year lease, can instead book time when it is needed. In general, technology will enable building owners to uncover models other than long-term leases based on square footage.

Emerging and significant externality costs. Numerous macroeconomic, geopolitical and technological forces are expected to continue to impact building operations in the coming year and decades. Climate change, as an example, will continue to raise carbon emission costs. Synapse Energy Economics in its Spring 2016 National Carbon Dioxide Price Forecast predicted that midpoint CO_2 per ton price will rise from approximately $20 in 2022 to $80 by 2050.[55] As another example, cybersecurity is expected to pose growing challenges to building security from human, asset and data standpoints. IBTs will help minimize such externality costs that otherwise might become significant financial and operational burdens for buildings.

Transactive energy. When intelligent buildings are nodes on a smart electric grid, they are able to automatically curtail load based on network signals. This increases grid reliability but also enables the buildings to become both buyers and sellers of electricity. They could sell their ability to reduce demand, widely known as automated demand response (ADR). With the use of renewable energy, they could also sell available electrons to other consumers. The Brooklyn Microgrid is one example of a local community working together to make energy generation and consumption more transactive at a local scale.[56] In this case, blockchain is used to reduce the burden of recording and monitoring the individual transactions between consumers - both buying and selling.[57] Distributed generation capacities such as renewable, energy storage and microgrids will continue to penetrate

[54] Brynjolfsson, Erik, and Andrew McAfee. "The Second Machine Age", page 102.
[55] http://www.synapse-energy.com/project/synapse-carbon-dioxide-price-forecast
[56] See https://www.brooklyn.energy for more details.
[57] http://www.power-technology.com/features/featurethe-brooklyn-microgrid-blockchain-enabled-community-power-5783564/

the commercial property markets such as hospital, office, university and municipality complexes. As this occurs, the universe of IBTs will incorporate features and capabilities such as blockchain and other fintech innovations that enable buildings to participate in more intelligent energy and carbon transactions.

Conclusion

Thanks to the accelerating development and convergence of various hardware, software, sensor and communications technologies, the age when buildings lag other segments of the economy in technology adoption is coming to an end. An unprecedented number of intelligent building technologies, or IBTs, have now been commercialized and countless more are being developed that can now bring the Internet-of-Things (IoT) into reality to vastly elevate building performance. The IBTs, when installed and adopted, are poised to dramatically increase building energy efficiency, operating efficiency, occupant comfort and productivity, and safety and security. The "3-30-300™" rule of thumb in the real estate market—the cost of energy ($3), rent ($30) and personnel cost ($300) per square foot—suggests that there are enormous operational, energy and productivity savings and benefits to be realized by adopting IBTs.

In the meantime, adoption of IBTs by government, businesses, and nonprofit organizations have been slow thus far. Some of the causes of this slow adoption—chief among them technology risk aversion, bureaucratic inertia, uncertainty on return on investment, and budget constraint—have been discussed in this paper. This undercuts the enormous impact IBTs could have on organizational competitiveness, economic growth, and global sustainability.

Over the past twenty years, software-as-a-service revolutionized how technology is sold to enterprises. The IBT-as-a-service model has potential to be the financial innovation needed to unlock the potential for buildings to adopt advanced technology solutions. IBTaaS removes the technology and product performance risk, budget constraint, technology obsolescence risk, uncertainty on return on investment, and need for maintenance resources. By adopting IBTaaS model for IBT adoption, building owners and facility managers can instead focus on expanding their core competencies and ensuring that their building investments align with the top-line, long term as well as bottom-line, short-term goals. And by avoiding typical organizational decision-making obstacles for new technology adoptions, building owners, operators and tenants can realize benefits from the latest IBTs in the most timely manner, optimizing building energy, equipment and human performance to achieve better profitability, sustainability, productivity and security. In other words, they can transform their real estate into a portfolio of smart buildings.