Decarbonizing the Built World: A Call to Action

A Digital Twin Consortium White Paper

2023-03-07

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1 DECARBONIZING THE BUILT WORLD: A CALL TO ACTION

Energy consumption in the USA is well documented by the Federal Energy Information Administration[1] and the Environmental Protection Agency[2] as one of the largest contributors to Greenhouse Gas (GHG) emissions adding to the climate crisis. The built environment is responsible for the majority of energy consumption and natural resource depletion.

To quote from Building Green[3]:

> *Having 41% of U.S. energy consumption attributed to buildings is huge. A very similar metric has to do with greenhouse gas emissions. The percentage is slightly different—because some energy sources are more carbon-intensive than others—but the difference is minor. Buildings account for 40% of total greenhouse gas emissions in the U.S. (usually reported as carbon dioxide or carbon equivalents).*

The problem is well documented by Science-Based Target Initiatives[4] and various global climate and data scientists yet the community of stakeholders that are involved in the building lifecycle process including financiers, risk auditors, developers, owners, operators, builders, city planners, technicians, trade partners, and suppliers that contributes to these emissions has yet to collectively accept responsibility and collaboratively reduce that negative environmental impact.

This white paper, compiled by practitioners from the AECO Working Group of the Digital Twin Consortium outlines how building owners, and their supporting community of stakeholders, can address the problem through the application of performance-based digital twins.

The Group started with a vision of "Author a series of user guides to assist an Owner or Occupier led implementation of the digital twin related capabilities that are required in supporting overall new or existing building decarbonization throughout the lifecycle*"*.

Through workshops with experts in the field, this was resolved into five questions:

1. Why should we do this? What are the Objectives for Sustainability, Efficiency, Resiliency, Health, Risk Mitigation, Performance, Reliability, Accountability? (Outcomes)
2. Who are the Stakeholders and how should they participate? (Who and when)
3. What is the Recommended Building Lifecycle? (requirements / content)
4. How does the Project Delivery Process need to be changed? (Physical Process)
5. How does the Digital Thread need to be enabled? (Virtual Process)

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[1] *https://www.eia.gov/*
[2] *https://www.epa.gov/ghgemissions*
[3] *https://www.buildinggreen.com/blog/energy-use-buildings-and-built-environment*
[4] *https://sciencebasedtargets.org/how-it-works*

This white paper serves as an introduction to the subject of how Building Performance and Sustainability can tackle the problem of both embodied and operational carbon emissions (also referenced as Scope 1, 2 and 3 GHG), and the five supporting user guides provide practical detail on how to address each of the questions within your organizations.

Please join us on the journey to decarbonize the built environment by using science and technology to reduce our collective carbon footprint.

2 EVOLUTION OF ENVIRONMENTAL INITIATIVES

Early environmental trends, at the beginning of the century, were driven by the opportunity of immediate cost savings, image enhancement, and quick brand marketing wins. These initiatives were led by high profile companies in many industries. This encouraged aspirational goals and commitments, sometimes with little detail to support them.

Organizations focused on employee-facing initiatives that drove social celebrations and created feelings of environmental consciousness. The Environment, Social and Governance (ESG) initiative was born. Due to recent COVID and health related impacts on the built environment, humans have become more aware of their surroundings and so we add the "H" into ESG+H to weave in the complex symbiosis between environmental health and human health conditions.

Companies in more asset-intensive industries realized the impact environmental initiatives could have to their bottom lines, most notably, their access to capital when aligned with the acronym ESG: green investing took off to develop the concept of the Triple Bottom Line[5] – that is the critical focus and alignment of the three "Ps" – People, Profit and Planet. Green investment funds began as a new category of investments that chose stocks based on the companies' commitment to ESG compliance.

Alongside this is the rapid adoption of human health and wellness integration as part of the larger ESG movement, something that is referred to as "ESG+H" and is critical considering the entire concept of the built environment revolves around people. Human health and comfort are a critical factor when discussing ESG, often omitted from the conversation when really, people are at the center of the equation.

While the rubric used to measure ESG is different for every financial management firm and industry organization, green funds drive investment. According to Morningstar, sustainability managed assets in the U.S. alone reached $357 billion in December 2021, a 51% increase from 2020.[6]

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[5] *https://www.business.com/articles/triple-bottom-line-defined/*

[6] *https://www.morningstar.com/articles/1076648/sustainable-fund-flows-dip-for-the-quarter-but-peak-for-the-year*

Aspirations do not produce good results without method and measurement along with qualification and quantification.

However, the market is experiencing some backlash toward ESG funding sources evident in the use of the term "greenwashing". Greenwashing refers to companies, knowingly or unknowingly, presenting themselves as environmentally conscious while not delivering on their written ESG commitments. While ESG compliance and standard metrics will bring some clarity, our focus is on the methods that will lead toward the development of decarbonization tools and strategies in the built environment through the application of digital twin related process and technology and showing all stakeholders how to do their part to help reduce Global Warming Potential[7], or GWP, and climate change.

Most importantly, the digital twin can be leveraged as part of the corporate compliance and validation of ESG standards, codes, ethics, incentives and penalties. All too often, balance sheets omit certain aspects which makes "achieving" ESG more easily attainable, hence the need for transparency in reporting and standardization across sectors.

Our built world community is obligated to act rapidly, with care, and be held accountable. If the data presented in the references is unconvincing in terms of decarbonization, net-zero, climate positive, and carbon-negative initiatives, we should ask ourselves if there is an alternative. What is the potential price of inaction?

3 THE OUTCOMES

Our focus on decarbonization should include outcomes required to achieve Sustainability, Efficiency, Resiliency, Improvements in Human Health, Risk Mitigation, and Reliability for our built environment. This impacts both new and existing built assets and the associated infrastructure.

New buildings consume steel, concrete, and glass which together account for about 11% of the total energy and CO_2 emissions[8]. The marketplace is rapidly developing alternative systems and innovative materials to achieve efficient decarbonization processes. The use of mass timber is one very good option as we consider the decarbonization of future buildings. In providing complete answers to Question 1, we must examine other outcomes.

The focus cannot be solely on new buildings. The life of a building is measured in decades and centuries. How can the life of those buildings be extended in a beneficial and energy efficient manner so that the embodied carbon contained in those buildings is not lost? The circular economy is not applicable to just the consumer markets. The AECO Working Group has already

[7] *https://www.epa.gov/ghgemissions/understanding-global-warming-potentials*

[8] IPCC, 2022: Summary for Policymakers. In: Climate Change 2022: Impacts, Adaptation and Vulnerability: *https://www.ipcc.ch/report/ar6/wg2/downloads/*

studied the building lifecycle and published a technical brief, "Infrastructure Lifecyle: A Case for Change[9]," which calls for a different perspective incorporating lessons from manufacturing.

In answering Question 1, the focus was on:

1. External drivers that impact owners and occupiers
2. How to convert these drivers into actionable projects
3. The scope of these projects, including carbon, water and wastes, and pollution, materials, energy and human effort.

4 THE STAKEHOLDERS

Why does the built environment have such a profound effect on the overall use of carbon and yet have relatively fewer, committed decision makers addressing 40% of the problem? Can this be changed? One of the most vexing challenges to decarbonization is the disparate nature of the built environment and the need for collaboration in making environmentally conscious decisions that are well-executed throughout the entire building lifecycle.

This is not a problem that can be addressed transactionally. Reaching efficient and effective decarbonization requires a strategic, focused, and calibrated effort across a broad group of stakeholders. Figure 4-1 below provides an illustration of the phases involved in our building lifecycle. How this evolved, and a description of each phase, can be found in the original paper, which is referenced.

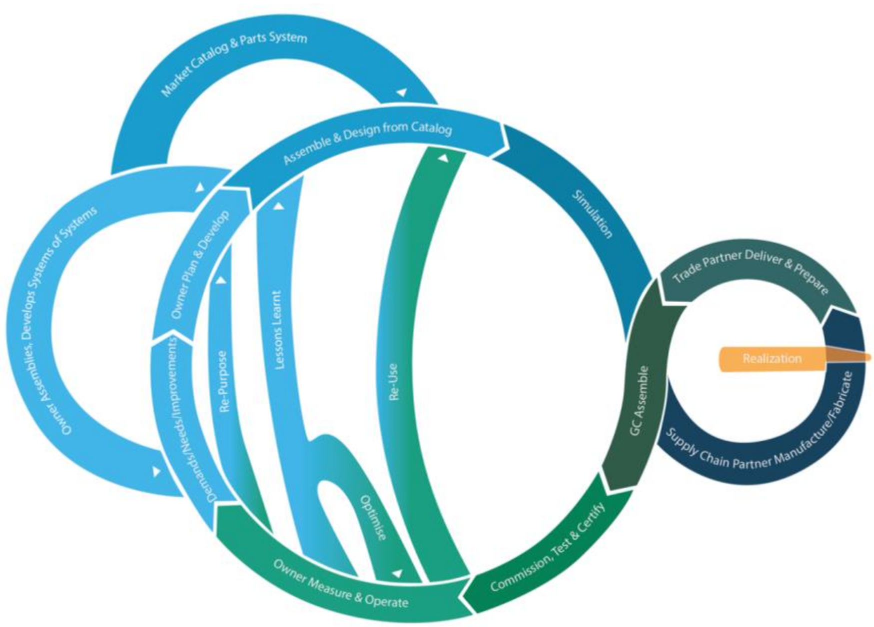

Figure 4-1: Digital building lifecycle.[10]

[9] *https://www.digitaltwinconsortium.org/infrastructure-lifecycle-a-case-for-change-form/*
[10] *https://www.digitaltwinconsortium.org/infrastructure-lifecycle-a-case-for-change-form/*

There are many different roles involved in this ongoing continuous lifecycle. To provide an analogy there are many different instruments involved in an orchestra, but there is only one conductor with the role to organize them, unite them and incentivize them to work together toward one collective, comprehensive, and meaningful outcome.

The analogy serves to illustrate the role that the Owner, public or private, must play in this process. In the same manner as a great orchestra may invite a guest conductor who specializes in one composer, the Owner may need to invite an Owner's Performance Advocate (OPA) to manage this new and unfamiliar process.

While there is no end to the list of stakeholders involved in the built world, there are four broad categories of stakeholders:

A. Building Ownership Stakeholders
B. AEC Community
C. Technology Vendors
D. People and Community

A. Building Ownership

The role buildings play in energy consumption, human health and well-being has never been more evident or more important. There are volumes of evolving evidence underscoring the relationship between the physical environment, energy consumption and human health. The evidence shows direct links to design, policy and built environment strategies and carbon consumption, health and well-being outcomes.

The knowledge base exists to create spaces that consume less carbon and enhance, rather than hinder, health and well-being resulting in higher productivity rates, increased ROI and better products or services. Building owners and developers are transforming buildings in ways that consume less carbon as well as advance health and well-being to help people thrive. Building ownership stakeholders include owners and developers, investors, tenants, building operators, facility managers, and vendors along the supply chain.

B. AEC Community

The AEC Community, comprised of architects, engineers, consultants, contractors, subcontractors, material suppliers, equipment vendors, and utility providers all have influence on the carbon footprint of the built world. These are the professionals offering their advice on the design, materials, construction, etc. They are often given immense influence on the outcome of a building or asset considering their areas of expertise and can heavily guide the first group of building owners to achieve a shared vision if set forth at project initiation Value Engineering exercise within the community need to be considered a holistic impact, not an immediate cost savings occasion, but rather, a long-term cost and carbon savings opportunity.

C. Smart Building Technology Vendors

Smart Building technology vendors provide the engine enabling achieving environmental targets. They provide the data to improve decision-making and drive the analytics behind what it means to run an environmentally friendly portfolio of buildings. This approach uses science-based targets, physics-based simulation, data analytics and proactive digital twins to align with the overarching goals of enabling decarbonization roadmaps and strategies.

D. People and Community

The last group we break out is people, the ones working, living and otherwise experiencing these buildings, and the organizations that drive regulations and standards, whether from federal or local governments or private sector industry entities. There are volumes of evolving evidence underscoring the relationship between the physical environment, carbon consumption and human health. The evidence shows direct links to design, policy and built environment strategies and health and well-being outcomes. The stakeholders we look to as part of people and community are: international environmental groups; federal, state and local governmental regulators; standards organizations; sustainability certification programs; non-governmental organizations (NGOs); medical based data sources, and related industry associations.

It will take more than a village to solve these complex and intertwined problems.

5 Changing the Building Lifecycle

To reduce and eventually reverse the environmental damage that is being caused by our built environment, including buildings, portfolios, cities, and infrastructures will need to be re-imagined as an indivisible component of a larger, constantly regenerating and self-sustaining system. No longer will the initial stages of construction be separated from the later stages of building operation, tenant improvement, revamp, retrofit or demolition.

There needs to be a total shift in mindset and culture – a shift to a regenerative, circular, low carbon mind set with continuous improvements and interventions necessary to stay on course toward the ever-evolving approach to decarbonization. For example, the US Federal Sustainability Plan mandates net-zero emissions buildings by 2045, including a 50% reduction by 2032[11]. This mandate requires key actions, including using sustainable design standards, data-driven decision-making, waste reduction, increased use of recycled products, increased energy and water efficiency, addressing equity, and other factors listed at *www.sustainability.gov*.

The next few years will be decisive in shaping our collective future—now is the moment to act.

[11] *https://www.sustainability.gov/federalsustainabilityplan/*

This shift in mindset needs to be embedded at all stages and needs to embed performance evaluation right from the earliest kick-off discussions, with continued check-ins against agreed metrics throughout all stages of a building's lifecycle. We believe that encompassing a digital twin approach into this lifecycle is a key to decarbonizing the built environment. Without the critical insights provided by a digital twin approach, several questions are raised:

- How will all stakeholders understand how the decisions they make now will impact the performance of the building over its complete?
- How will they understand how a building responds to those decisions behaving like its real-world counterpart in different environmental, economic, and social conditions throughout its duration of operations?
- How will they simulate various options and confirm chosen options do in fact produce the intended results?

To deliver the data-driven information needed to uncover significant energy, carbon, capital, and operational savings the modeling and correlation capabilities of a proactive and closed-loop digital twin are required. By applying this approach within a wider context, the operator can take account of the environmental factors of where it is in the world, how dependent resources are modeled and used, and the impact of transport, social and economic factors.

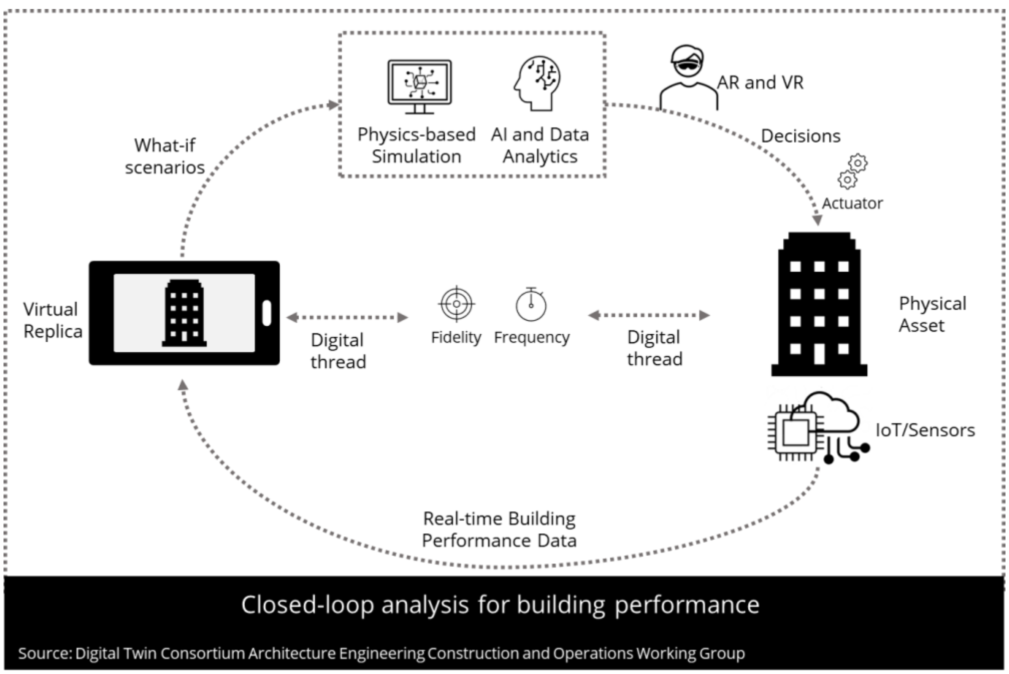

Figure 5-1: Closed-loop analysis for building performance[12].

To do this, the technology driving digital twins needs to incorporate reliable, physics-based simulation with the ability to more accurately predict operational building performance. The

[12] Digital Twin Consortium *AECO Working Group*.

digital twin needs to continuously monitor that performance and identify ways to calibrate and improve the operation of the building throughout its lifecycle.

Those lifecycle considerations, both project delivery and operational , need to be aligned with the insight that can be provided by such a model, and the physical asset calibrated against the equivalent virtual asset to ensure efficient performance, often referred to as continuous Model-Based Commissioning (MBx).

The benefits of targeting higher building performance and using robust physics-based modelling right from the earliest conceptual design stages into building operation include:

- Improving the building energy and water efficiency that can lower energy bills.
- Investing in high performing building fabric that can improve indoor comfort, as well as the health and wellbeing of occupants.
- Engage good environmental design that can reduce comprehensive risks.
- Reduce and potentially avoid the need for retrofitting in future.
- Generate buildings that can adapt and change over time, while keeping high performance levels.
- Adopting protocols for inclusion of a cradle to cradle approach and repurposing versus the traditional cradle to grave approach, one and done mentality.

By leveraging a proactive digital twin strategy for enlightened owners whether the building is old or new, well-monitored or not, access to data or no data, the approach allows a comparison of how the building should be performing against how it is actually performing, often referred to as the “performance gap” Improvements can be modeled and informed investment decisions made.

Using the digital twin’s ability to perform “what-if” scenarios provide unlimited abilities to test and certify system and material selection using virtual time and virtual money to make decisions that reduce real money and environmental impact. The process provides the ability to build a cost-effective roadmap for validating both short-term and long-term decarbonization measures.

6 The Future of Project Delivery

The digital transformation of our buildings so that they perform more efficiently will have to be mirrored by a transformation of the process by which they are designed, constructed, and operated. This has been referenced in the technical brief “Infrastructure Lifecycle: A Case for Change[13].” As the lifecycle transforms so must the delivery process for proper alignment.

Architects have posed the question, “Does form follow function or function follow form?” Our investigation has indicated that in the case of building performance, function must be a fundamental part of the building specification process at the point of design inception, along with

[13] *www.digitaltwinconsortium.org/infrastructure-lifecycle-a-case-for-change-form/*

building standards, Basis of Design (BOD), Building Information Modelling (BIM) standards, and Building Energy Modeling standards. If the building is to perform, from a decarbonization perspective, then the process by which these standards are applied and enforced through the building lifecycle must be managed.

A simulation model of the building's performance is a critical component of this process of project delivery. This will fundamentally change the conventional process of project delivery. To manage this, it is suggested that a new role of Owner Performance Advocate needs to be established to manage the digital building lifecycle in parallel with the Owner Representative who is managing the initial stages of the conventional building lifecycle.

This introduces two major differences:

1. A conventional Owner's Representative approach traditionally focuses on physical buildings and not on digital representations of physical buildings, or digital twin. In the near future, these disciplines will merge but we don't expect that to happen until practitioners are able to equally represent and embrace building science backed by data science.
2. A conventional Owner's Representative traditionally focuses on the stages prior to handover to the Facilities Management Team. An Owner's Performance Advocate takes a complete lifecycle approach to delivering building performance results and the outcomes as laid out in a contemporary Owner's Project Requirements (OPR).

There is a saying that the insanity of management is to expect the same people doing the same things to produce different outcomes. Building performance and sustainability optimization demand a different approach which must start in early conceptual planning. The conventional design process needs to be changed with the following focuses:

- Integrate new contracting documents that eliminate silos in conventional processes.
- Focus on the larger portfolio approaches rather than project perspective – need for scalability.
- Provide access to a single energy/carbon model shared with all team stakeholders.
- Full team commitment to collaborative and integrated processes early in design process
- Deploy building energy modelling before design development and validated as design modifications are introduced.
- Integrate decision-making using data and information management processes.
- Provide value engineering options with data demonstrating impacts to building performance, first costs and long-term operating costs.

Each of these topics is examined in detail in the accompanying user guides.

7 ENABLING A DIGITAL THREAD

The Digital Twin Consortium Glossary defines a digital twin as follows[14]:

A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity.

- *Digital twin systems transform business by accelerating holistic understanding, optimal decision-making, and effective action.*
- *Digital twins use real-time and historical data to represent the past and present and simulate predicted futures.*
- *Digital twins are motivated by outcomes, tailored to use cases, powered by integration, built on consistent data, guided by domain knowledge, and implemented in IT/OT systems.*

So, for a typical infrastructure project, the expectation is that we would normally have several virtual representations due to the complexity. Each of these are seamlessly connected into a Digital Thread

The Digital Twin Consortium Glossary defines the digital thread as[15]:

Digital Thread: a mechanism for correlating information across multiple dimensions of the virtual representation, where the dimensions include (but are not limited to) time or lifecycle stage (including design intent), kind-of-model, and configuration history; the mechanism generally relies on stable, consistent real-world identifiers.

- *Be populated with data flowing from upstream or previous time phases in the digital lifecycle, for example a digital twin focusing on operational use cases would need to be populated with data from Planning, Design, Procurement and Construction phases.*
- *Communicate with other systems within the same phase of the digital lifecycle.*
- *Pass data to downstream systems, which are systems that require the data in a later time phase of the digital lifecycle.*

The relevance of this definition to the Build Environment has been discussed in previous AECO Working Group papers, which have been referenced.

In terms of building performance, a digital twin is not just a virtual representation of the physical building that is synchronized at predetermined intervals. The built environment is complex and involves many stakeholders acting in many phases. In the traditional approach, the synchronization of these stakeholders through the multiple phases leveraging multiple systems in a “system of systems” approach may lead to many integration problems.

[14] *https://www.digitaltwinconsortium.org/glossary/glossary/#digital-twin*
[15] *https://www.digitaltwinconsortium.org/glossary/glossary/#digital-thread*

Conventionally, much of this data is held in two-dimensional paper format, or their electronic equivalent. Significant amounts of data are often lost in translation, do not survive the cost of having to be converted from one form to another or are not able to be reconciled from a cost perspective back to an asset perspective. The collection of such data is very rarely driven by use cases which are central to the DTC definition of a digital twin.

Our investigation also showed that there could be multiple digital twins within the digital building lifecycle. Perhaps one for each of the Planning, Design, Procurement, Construction, Commissioning phases and multiple for the Operations and Maintenance Phases. In a true system of systems approach none should be built in isolation. The importance of the digital thread in connecting all of them together in an efficient delivery mechanism is critical and a necessary step to the decarbonization of the built environment.

The digital twin can also be commissioned and adopted at different levels according to the use cases that drive the business case. The following levels of complexity and sophistication for building performance and sustainability measurement and improvement were identified and are discussed in more detail in the supporting documents:

1. Level 1: descriptive digital twins (for collecting and visualizing data)
2. Level 2: informative digital twins (converting data into information for generating insights)
3. Level 3: predictive digital twins (using real-time data to predict future state)
4. Level 4: comprehensive proactive digital twins (combining levels 1, 2, and 3 to propose interventions for avoiding problems and achieving better outcomes)
5. Level 5: autonomous and connected digital twins (using artificial intelligence (AI) and machine learning (ML) to reduce dependence on human intervention)

Data and information management are crucial in enabling digital twins for optimizing building performance and sustainability to align with ESG metrics. Digital twins, first and foremost, rely on accurate, trusted, and reliable data and information about the building and its sub-components over their life cycle. Data are central to digital twins' development, deployment, and use; indeed, it could be argued that data and information are the “point” of digital twins.

Where there is missing or unavailable data, the performance-based digital twins can generate data rather than arbitrarily accepting a mythological baseline. In our supplemental guide, we further explain these levels of complexity and sophistication, discuss how to best align with business goals, and discuss recommendations and best practices.

8 Industry Call to Action

In our accompanying supplemental guides, each of the five questions below are examined in more detail. Practical suggestions are given, and references are provided. If these answers were obvious, then there would be no need for this paper.

What is obvious, however, is that we need to provide transformational thinking to solve these problems. We need to apply technology, but technology alone will never be the silver bullet. We need to change the way we approach the building lifecycle. We need to incorporate the digital building lifecycle into the physical lifecycle and focus on two deliverables; the physical building and the virtual building (its digital twin) to unlock the power of the digital thread to support use cases that focus on delivering the Decarbonization, Building Performance, Sustainability, Resiliency, Risk Mitigation, and Reliability Outcomes to which we aspire.

The key takeaways from our guidance are:

1. Focus initially on reducing the use of energy (apply Energy Conservation Methods – or commonly referred as ECMs) to directly reduce carbon. Only after minimizing operating carbon should we then focus on reducing embodied carbon in new builds.

2. Leverage a performance-based digital twin model for both new and existing buildings such that a holistic and predictable outcome can be applied to all buildings within the portfolio which serves to de-risk investments.

3. Measure actual performance today against a simulated version of what a building is capable of achieving. The latest 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (Paris Agreement (COP27)[16] illustrated that our current methods of measuring trended performance in isolation are not enough. We must apply scientific, data-backed dynamic modeling methods to back up stated ESG goals.

4. Coordinating compliance with standards and permits alone will not advance decarbonization quickly enough. Often, governmental code compliance standards are too late. Carbon offsets treat the symptom and not the problem. Leaders will be recognized, and failures will be punished.

5. Develop a strategy to start small but start now and iterate quickly. Measure your success and learn quickly from your failures. There is not much time left to do the right thing for the planet, society, children, the economic performance of your corporation and for your career.

We look forward to you joining us on this exciting journey!

[16] *https://www.un.org/en/climatechange/cop27*

AUTHORS & LEGAL NOTICE

This document is a work product of the Digital Twin Consortium Architecture, Engineering, Construction & Operations (AECO) Working Group, chaired by Chris Heger (OAC), Salla Eckhardt (OAC), and Anil Sawhney (RICS), and the Building Performance Tiger Team, chaired by John Turner (Gafcon Digital).

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Technical Editor: Dan Isaacs (DTC CTO) oversaw the process of organizing the contributions of the above Authors and Editors into an integrated document.