The Ultimate Guide to Sustainable Construction Technology: Good, Better, and Best.

Trimble

Introduction

Construction stakeholders, from owners to designers and architects, to contractors, are under pressure to produce more sustainable assets. Using sustainable materials and design methodologies are key strategies, but they must be part of a more holistic effort.

Materials selection and design processes play an important role in reducing construction's environmental impact, but they're not enough on their own. To make the required improvements in sustainability, stakeholders must commit to addressing the inefficiencies, rework, and waste throughout the asset lifecycle, beginning with design and continuing through operations and maintenance.

Even the most meticulous designers unwittingly create models that contain errors, omissions, or conflicts. Due to the traditional siloed nature of project workflows, these mistakes can often go unnoticed until the construction phase begins.

Contractors and subcontractors take it upon themselves to resolve conflicts, often recreating their own models to complete their deliverables — which is where the rework begins.

At every stage, stakeholders collect important information that could be valuable later in the project lifecycle. But much of that data goes unused due to a lack of portability and collaboration.

Along the way, workers lose time recreating models and gathering information between the office and the field. A significant portion of machine time is dedicated to repeat tasks, and materials, fuel, and labor hours go to waste. Owners begin the operations phase without key data that could help streamline ongoing maintenance.

To fully address sustainability concerns, stakeholders need to increase collaboration and data sharing, starting with the initial planning phases of a project and continuing through to asset management.

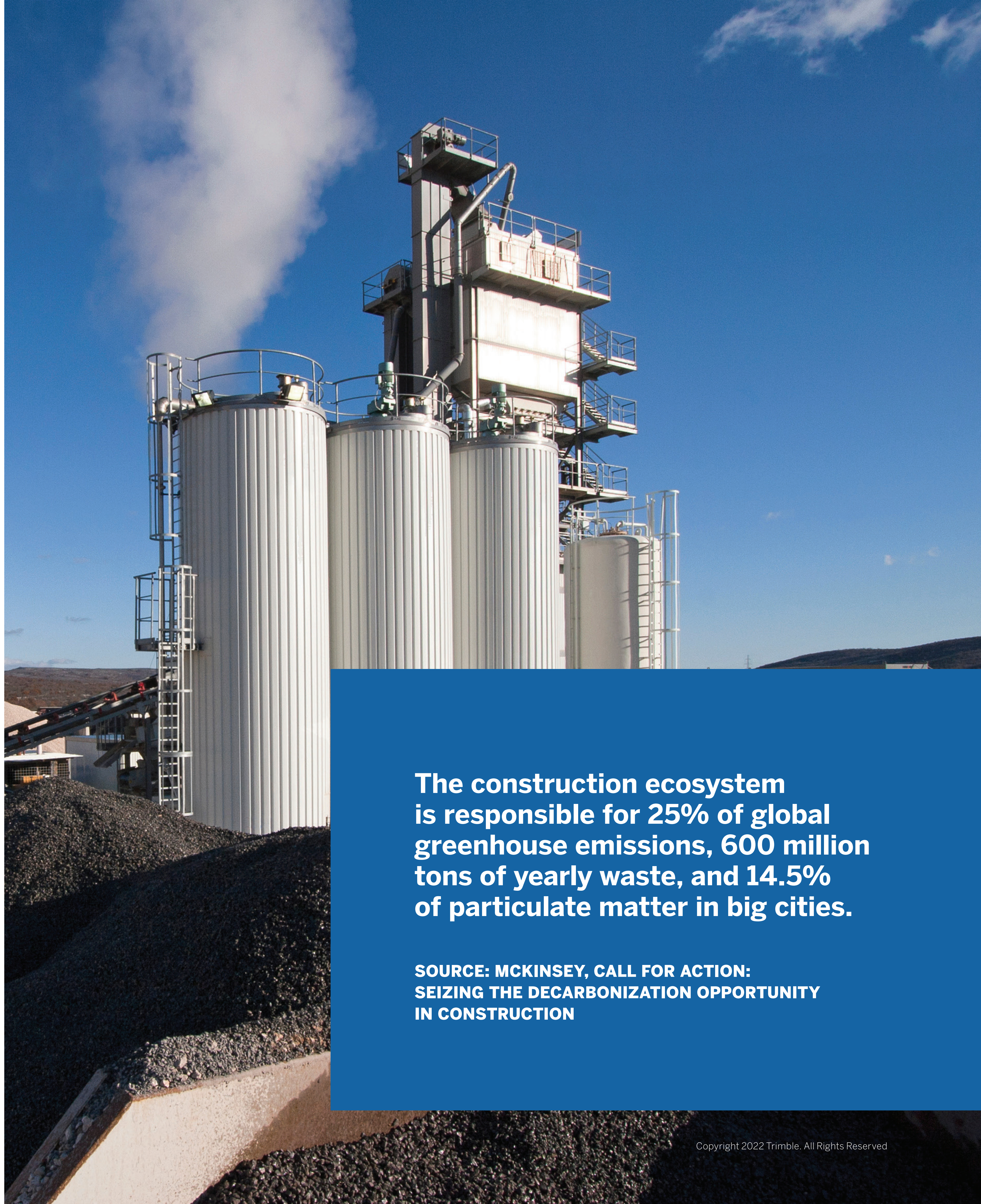
A connected construction approach offers a means of designing, building, and operating more sustainable assets. By providing the technology and interconnectivity, connected construction gives the right people the right data at the right time.

When everyone involved in the project has access to the information they need to detect problems earlier and make better and faster decisions, waste and rework are minimized.

While it may seem like an overwhelming proposition, you likely have some of the foundational components of connected construction.

Read on to deepen your understanding of:

- Why technology is critical to improving sustainability throughout the project lifecycle
- What technologies are needed to support a connected construction approach
- Where you should make technology investments to achieve your sustainability goals



The construction ecosystem is responsible for 25% of global greenhouse emissions, 600 million tons of yearly waste, and 14.5% of particulate matter in big cities.

SOURCE: MCKINSEY, CALL FOR ACTION: SEIZING THE DECARBONIZATION OPPORTUNITY IN CONSTRUCTION

Raw materials consumption is expected to reach 167 Gigatonnes in 2060, a majority of which will be used in construction.

— ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD), GLOBAL MATERIAL RESOURCES OUTLOOK TO 2060

The New Scope of Sustainability

The scope of sustainability is evolving as the climate crisis grows more urgent and awareness of environmental issues plays an increasingly important role in buyer and investor decision-making.

Until recently, sustainable construction focused primarily on reducing energy consumption during the operations phase of assets, with less emphasis on the construction process itself.

The need to rethink what sustainability entails is made more urgent by the shrinking window to address climate change. We're quickly approaching the 1.5° warming threshold set by the Paris Climate Agreement and other climate-focused initiatives. Simply swapping out traditional materials for new ones isn't enough. We must reduce consumption.

It's estimated that up to 20% of construction materials go to waste. Wasting materials doesn't just deplete resources–it also generates unnecessary emissions. According to the World Green Building Council, embodied carbon, the greenhouse gasses emitted by the extraction, processing, and installation of construction materials, is expected to account for half of construction emissions between now and 2050.

Reducing consumption requires reducing waste. Green materials and energy-efficient mechanical systems aren't enough anymore. We need to transform workflows so that unnecessary waste and massive emissions are no longer written off as a "cost of doing business."Clients, investors, and asset users are increasingly aware of these issues and expect project stakeholders to address them as part of their broader environmental, sustainability, and governance (ESG) programs.

Using Technology to Address Sustainability Challenges

When it comes to technology decisions, your strategic priorities, budget, team capabilities, and client/user expectations all play a role in determining which tools you adopt.

Any new technology investment must enhance your current capabilities and make processes more efficient and seamless, not more complicated. And while reducing construction's environmental impact is mission critical, you also need to start where you're at. Otherwise you may find yourself overpowered by technology instead of empowered by it.

Making smart technology investments is a critical step in addressing sustainability challenges. In the sections that follow, you'll learn about the technologies available, and how each contributes to improvements in sustainability — both in terms of individual capabilities and as part of a connected construction ecosystem.

Good

- 3D Modeling Software
- Common Data Environment (CDE)
- Project Management System

Better

- Building Information Modeling (BIM) Tools
- Feasibility Planning Software
- Extended Reality Technologies
- Building Performance Analysis & Environmental Modeling Software
- Machine Control Systems
- Positioning Technologies
- Enterprise Asset Management (EAM) Software
- Building Management System
- Fleet & Equipment Management System

Best

- Robots
- Autonomous (Driverless) Equipment
- IoT Sensors
- Thermal Imaging Technology
- Digital Twins & Asset Information Models (AIMs)
- Generative Design
- Model-based Estimating & Takeoff

Good

The three technologies outlined in this section represent the foundational components needed. They close gaps between construction teams, which sets the foundation for better communication, workflow management, and decision-making. Because so much construction waste and inefficiency is caused by poor collaboration, being “good” at construction sustainability requires breaking down walls between traditionally siloed teams.

You’ve got to start somewhere, and we recommend you start here.

3D Modeling Software

Allows designers to quickly explore new ideas and spot conflicts early

Can be embedded with data that supports efficient and accurate processes, from estimating to earthmoving

Makes data available to project stakeholders throughout the project lifecycle, reducing waste and inefficiencies

Incorporating 3D modeling capabilities is often one of the first steps AEC firms take to improve their technology. By creating more realistic, data-rich models, designers can explore different ideas more quickly and spot conflicts early. 3D models set the foundation for many of the other technologies discussed in this guide, acting as the centerpiece for collaborative team processes.

Performance modeling, estimating, and so many other critical construction processes benefit from being able to retrieve data from a 3D model. Having the ability to capture, share, and test data-rich models leads to fewer errors and mistakes in preconstruction, construction, and operations and maintenance. And it allows for better data collection and continuity throughout the project. That's what's needed to reduce inefficiencies and waste throughout the construction ecosystem.

Common Data Environment (CDE)

Provides a single source of truth for all phases of the project lifecycle, improving productivity and transparency

Enables project teams to access data, track tasks, and record project details from the office and the field

Can be enhanced with additional capabilities (e.g., model viewing) to further support collaboration

A common data environment (CDE) provides a single source of truth for all phases of the project lifecycle so stakeholders can communicate more seamlessly and accurately, improving productivity at scale. From the job site to the office, teams can access data, log tasks, and document project details into a cloud-based system. A CDE can be as basic as a digital file folder system. However, to drive construction sustainability, project teams should take advantage of more robust solutions that allow for higher levels of collaboration.

For example, a good CDE solution is capable of consolidating models and project data from disparate systems, which enables project teams to reduce the confusion and waste of version control and poor data access. Better data access leads to better planning and decision-making. Planning high-performing assets like net zero buildings requires project teams to integrate with one another and deliver asset owners the information they need to operate effectively. Solving complex sustainability challenges is easier when everyone is working with the same data set.

How to Get the Most from a CDE

To realize the full time-saving, error-reducing potential of a CDE to support your sustainability initiatives, incorporate the following best practices:

Give the right people the right access at the right time.
Prevent the confusion of sharing project data too early, or too late, by segmenting users into groups.

Support the need for individual CDEs.
It may be a good idea for some subcontractors to use their own CDE to protect proprietary information and prevent data overload for the larger project team.

Look for one-to-one data mapping.
The right CDE will enable you to view models from disparate systems in a high-fidelity format without sacrificing data integrity.

Automate workflows using APIs.
Integrate the CDE with other systems to automate invoicing, trigger tasks, and reduce manually sharing data with other systems throughout the project and enterprise.

Capture only the data you really need.
Data is only useful when it's accurate and relevant. Configure your CDE to capture only the data that is required for the project and useful to the teams involved.

Leverage open sharing standards.
An effective CDE treats all data equally, regardless of the program or tool it originates from.

Work from a single continuous model.
When every collaborator works on one single continuous model, instead of uploading new files every time a change is made, version control is no longer an issue. Better model interactivity also supports Level 3 BIM maturity, which is focused on sharing complete project information throughout the lifecycle of an asset.

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Project Management System

Automates project updates, approvals, and alerts to ease friction between stakeholders

Provides real-time project monitoring to ensure sustainable measures are actually being implemented

Empowers project managers to predict the downstream impacts of change orders and other adjustments

Project management systems give construction teams greater control over the risks that commonly lead to waste and inefficiencies. Automating project updates, alerts, and approvals reduces friction between multidisciplinary stakeholders. With real-time monitoring, they can potentially foresee the downstream impacts of change orders and resource management adjustments, which is where a lot of rework and waste happens. Higher visibility also ensures that sustainable materials and solutions are actually being implemented. And government owners can improve document management by integrating their project management tool with their permitting departments.

Here are three key areas where project management systems can improve construction sustainability:

1. Design Review

The process requires a high volume of printed documents and office space for storing those documents. Plans and models are scanned and shared via email, which can set off a snowball effect of version control issues. But with a project management system, the handoff process is automated to ensure that each reviewer performs their tasks at the right time. All documents and comments are captured within the system, ensuring all stakeholders have full visibility into the same information.

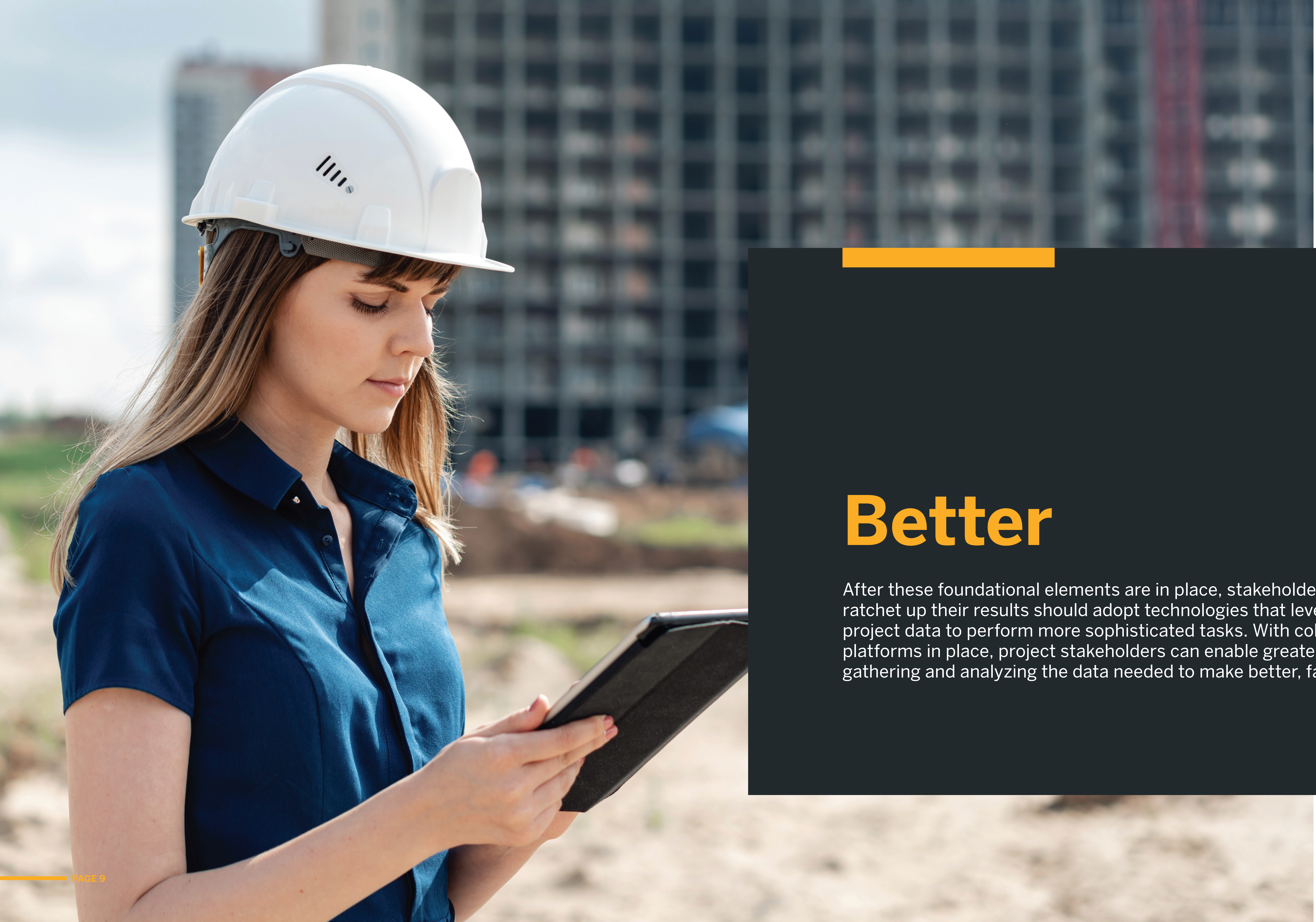
2. RFIs

Tracking and managing RFIs, which are still commonly paper-based, can be unwieldy. Owners typically have other administrative tasks to manage, and it's difficult to accurately route information in a timely fashion. With a project management system, you can standardize RFI forms and automate routing to the right stakeholders. Bids can be submitted to the same system, consolidating project communication and reducing any lingering paper-based processes.

3. Change Order Management

Whether they originate from a client request or a mistake, change orders are one of the most common sources of project inefficiencies and waste. A project management system allows each team member to see which stage the workflow is in, and all documents stored in the system can be updated to automatically reflect the change.

Project Management System Case Study: **Achieving Ambitious Goals for Green Infrastructure**



Better

After these foundational elements are in place, stakeholders looking to ratchet up their results should adopt technologies that leverage centralized project data to perform more sophisticated tasks. With collaborative platforms in place, project stakeholders can enable greater efficiencies by gathering and analyzing the data needed to make better, faster decisions.

Building Information Modeling (BIM) Tools

Can be used to connect multidisciplinary teams from pre- construction through operations and maintenance

Allows for automated clash detection, preventing material and resource waste caused by rework

Supports a more accurate measurement of whether a project meets sustainability goals

A holistic approach to sustainability starts at the beginning of design and BIM is one of the best ways to design. Each member of the project team can quickly access a full, real-time summary of the products and materials that are being proposed, how they will be fabricated and installed, and how they are expected to perform post-construction. BIM allows for clash detection, so materials and resources aren't wasted on ad hoc solutions or rework. It also makes it possible to assess project sustainability goals:

- Compare project energy efficiency and estimate LEED points
- Assess various designs for building code compliance
- Measure carbon emissions (both embodied and operational)

USING BIM BEYOND DESIGN

In the construction phase, BIM enables higher levels of efficiency by ensuring contractors receive accurate, consistent information for all the documentation involved in a project. That allows job site teams to get it right the first time, significantly cutting down on waste. With BIM, contractors can gain insights from individual projects over time to identify and address root causes of inefficiencies and waste.

BIM's usefulness extends into the operational phase of an asset by making design and construction data available to asset owners. It sets the foundation for the creation of a digital twin or asset information model, which are data-rich 3D models that facility managers can use to determine the right approach and materials needed to operate and maintain the asset efficiently. These digital representations of the asset can be used to plan preventive maintenance programs as well as retrofitting and retro commissioning. Operators can also use them to continually measure and optimize energy use and resource consumption.

BIM also improves outcomes for productized solutions, such as prefabrication and modular construction. These offsite construction methods improve sustainability significantly because conflicts and errors are resolved through early collaboration. It's easier to reduce and recycle waste in a controlled production environment, and materials and machinery are coordinated more efficiently on the job site.

Feasibility Planning Software

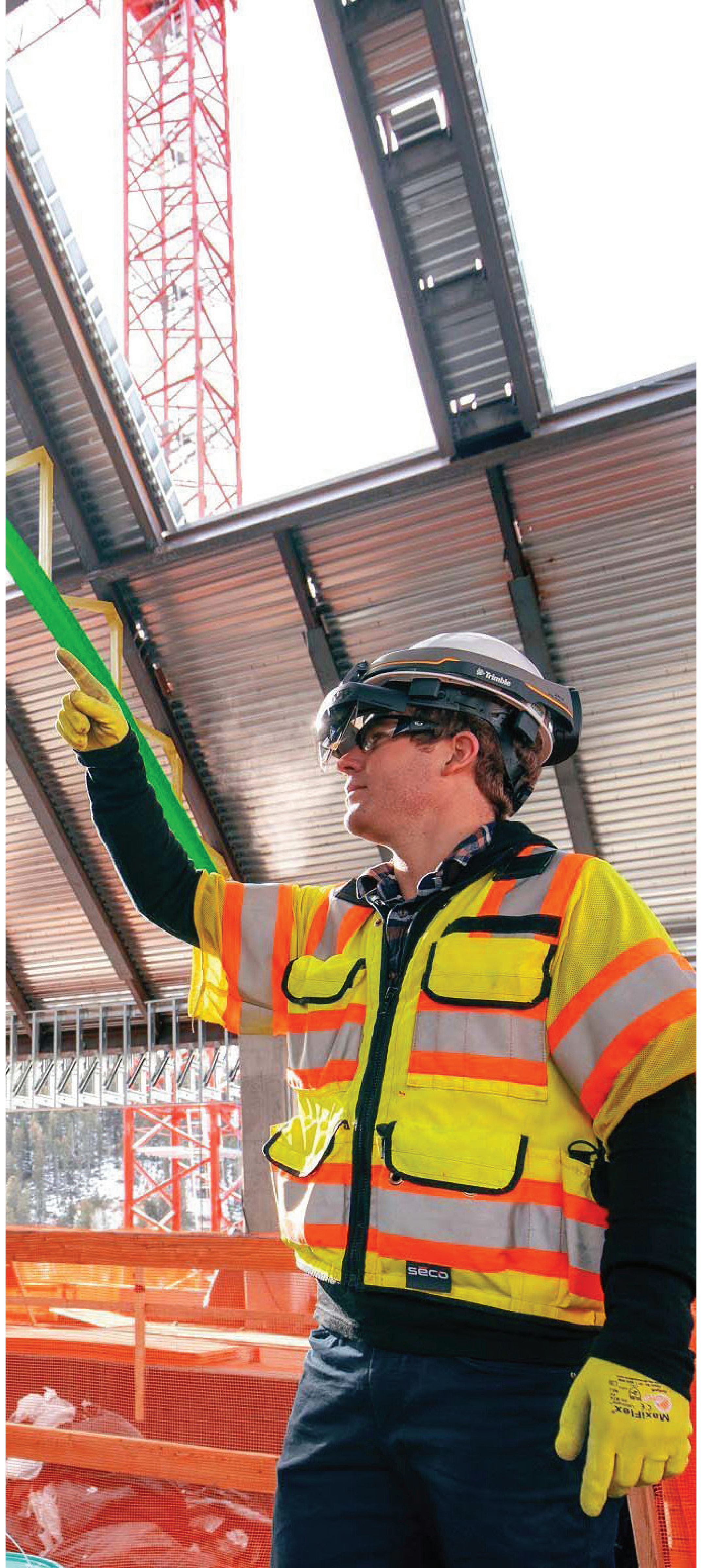
Allows civil planners to analyze a project's environmental and social impacts, as well as its ability to meet engineering requirements

Can combine environmental, community, cultural engineering, and cost factors into a single analysis

Supports greater transparency with the public, since teams can rapidly assess environmental considerations

Major transportation and utility projects have wide-ranging implications for local communities. Feasibility planning software is essential to bringing engineering and environmental teams together to analyze projects for environmental impact, social constraints, and ability to meet engineering requirements.

For example, engineers can forecast the CO_2 emissions that will be produced in the construction and operational phase of civil assets and understand traffic impacts after a project is completed. They can streamline environmental, community, cultural engineering, and cost factors into a single analysis, allowing them to feel confident that they've narrowed down their selection to the best options. During construction, engineers and designers can rapidly assess environmental considerations as the project unfolds and keep the public up to date on impacts.



Extended Reality Technologies

Can be used to simulate sustainable design strategies with realistic detail

Enables workers on the job site to view virtual models in the context of the real environment, reducing errors and rework

Empowers facility managers to see where critical systems are located behind walls, preventing wasteful mistakes

Extended reality technologies use mixed and augmented reality to visualize models in real-world environments, and they can be used to improve sustainability throughout the construction lifecycle.

Simulating Sustainable Design

BIM models can be translated to suit virtual reality (VR) technologies, which designers can then use in the design evaluation and project management process. They can simulate environmental and seasonal changes to assess issues like sun exposure, shading, and glare. Designers can assess whether daylighting strategies will pan out as they plan by using VR to assess lighting intensity and trajectory in realistic detail. Mixed reality technology can also be used to identify design conflicts and clashes before ground is broken.

Improving Onsite Processes

At the job site, workers can use wearables and tablets to view virtual models to minimize rework. For example, mechanical contractors can use mixed reality headsets to reduce the errors of hand detailing, visualize piping systems to scale in the actual environment, and coordinate with other trades to prevent conflicts. Materials for mechanical components often can't be reused or recycled once they've been fabricated. Extended reality helps ensure specifications are correct before fabrication. And when changes are needed, extended reality can be used to assess changes before wasting materials and fuel.

Enhancing Facility Management

If facility managers have access to an up-to-date asset model, it can support extended reality in operations and design. Augmented reality glasses or tablets can be used to see where mechanical, electrical, and plumbing systems are located behind walls. They can view structural elements to help inform future renovations. This insight prevents wasteful mistakes and helps owners make more strategic operations and maintenance decisions.

Building Performance Analysis & Environmental Modeling Software

Measures energy performance in varying scenarios to meet building codes, climate change objectives, and green certifications

Enables designers to understand how factors like airflow and lighting impact energy performance and efficiency

Allows for early assessment of energy needs and capabilities

Design decisions impact energy performance, and meeting building codes, climate change initiatives, and green certifications require design professionals to simulate and measure energy performance in varying scenarios. Building performance analysis software and environmental modeling allows you to understand how solar, thermal, lighting, visibility, and airflow factors impact energy performance and efficiency.

As sustainability initiatives call for increased use of renewables and grid interactivity, analysis and modeling tools enable architects to assess energy needs and capabilities early in the design process. For retrofits and renovations, performing whole-building energy modeling can incorporate actual weather and occupancy data to perform comparison between current and proposed states. The assessment can hone in on energy consumption generated by specific building systems to choose designs that deliver the highest level of efficiency.

Incorporating Energy Modeling in Every Project

JLG Architects is an award-winning design firm that has achieved numerous LEED certifications and has signed on to AIA's 2030 Commitment. The firm creates energy models for every 2030 reportable project, as well as completing an AIA framework for Design Excellence (FDE-10) for all projects. Each project is analyzed so JLG can continually identify energy efficiency, safety, and process improvements for future designs. Since implementing this approach the firm achieved a 55% energy reduction in 2020 compared to the 2030 baseline.

Achieving these objectives requires a holistic approach to sustainability. Here's how JLG does it, in five steps:

- **Doing is knowing:** JLG teams learn by doing, not just passively listening to instruction. This approach allows them to break the barrier of understanding to accelerate progress.
- **Always on:** Performance analysis is compulsory at JLG. Their energy modeling tool is set to automatically run alongside their 3D modeling tool so JLG's designers can assess every project.
- **Real-time design analytics:** Each team performs their own performance simulations with the support of specialists so designers and models are always kept up to date as the project develops.
- **Embed best practices and standardize repeat tasks:** By creating starter models for different building types in their performance modeling tool, JLG makes it easy for every designer to hit the ground running.
- **Normalize pushing the boundaries:** Teams are encouraged to test new ideas to better understand how different building factors affect energy performance.

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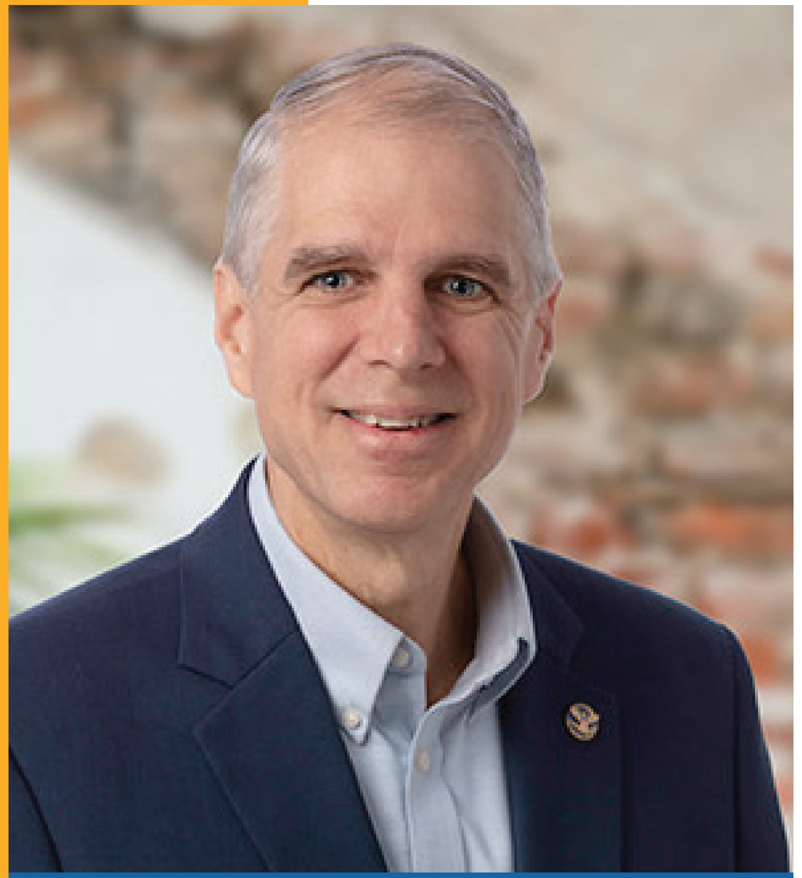


"Instead of designing a building like a stack of pancakes and then pouring sustainability syrup on after the fact, we're mixing sustainability into the design 'batter' from the beginning on every project."

— PATRICK THIBAUDEAU, PRINCIPAL SUSTAINABILITY OFFICER AT JLG

Projects that use energy modeling are 29% more energy efficient than projects that don't.

SOURCE: AMERICAN INSTITUTE OF ARCHITECTS

Nearly 2/3 of contractors say that being able to gather accurate data from the field contributes most to their ability to improve performance.

SOURCE: DODGE DATA & ANALYTICS, IMPROVING PERFORMANCE WITH SMART DATA

Machine Control Systems

Enables operators to position equipment more accurately, reducing errors and fuel waste

Can ensure that materials are weighed properly to prevent resource-intensive corrections

Automates machine tracking, as well as volume and compaction methods, to optimize equipment usage

Machine control enables operators to use 2D drawings and 3D models, along with global positioning systems (GPS), to accurately position equipment. Sensors and scales can be used to ensure materials are weighed accurately, taking the burden of guesswork off of operators. Correcting earthwork failures is resource-intensive. Getting it right the first time can lead to tremendous reductions in materials waste and fuel consumption.

With machine control, contractors can automatically track the location of machinery, along with volume and compaction methods, to monitor progress and allocate equipment where needed, so machines can be maximized without wasting fuel. Since machines are such a critical source of fuel consumption, being able to tie dirt moved to fuel burned, and perform larger analyses over time can have a significant impact on future improvements and efficiencies.

Contractors can reap the benefits of machine control regardless of whether they choose to purchase new equipment or upgrade their existing machines. If current equipment is in good working condition, it can be outfitted with machine control technology to reduce fuel consumption and minimize errors. And if contractors choose to invest in newer, more energy-efficient equipment, they can further reduce greenhouse gas emissions generated on the job site.

Positioning Technologies

Enables designers and engineers to assess assets for resilience and explore the feasibility of renovations

Requires fewer engineers to perform scans, reducing travel to and from the job site

Leverages a variety of data sets so project teams can track ecological change, assess cause and effect, and understand environmental impacts

Positioning technologies offer broad sustainability impacts across the construction sector–from building renovations to new infrastructure projects.

SCANNING TOOLS

3D scanning tools can be used to augment BIM models with a higher level of detail. For renovation projects, that higher level of detail allows engineers and designers to identify which building components can be preserved and explore sustainable solutions. The scanner provides an accurate 3D representation of existing conditions that can be used to assess whether a renovation is feasible, and what to expect once implemented.

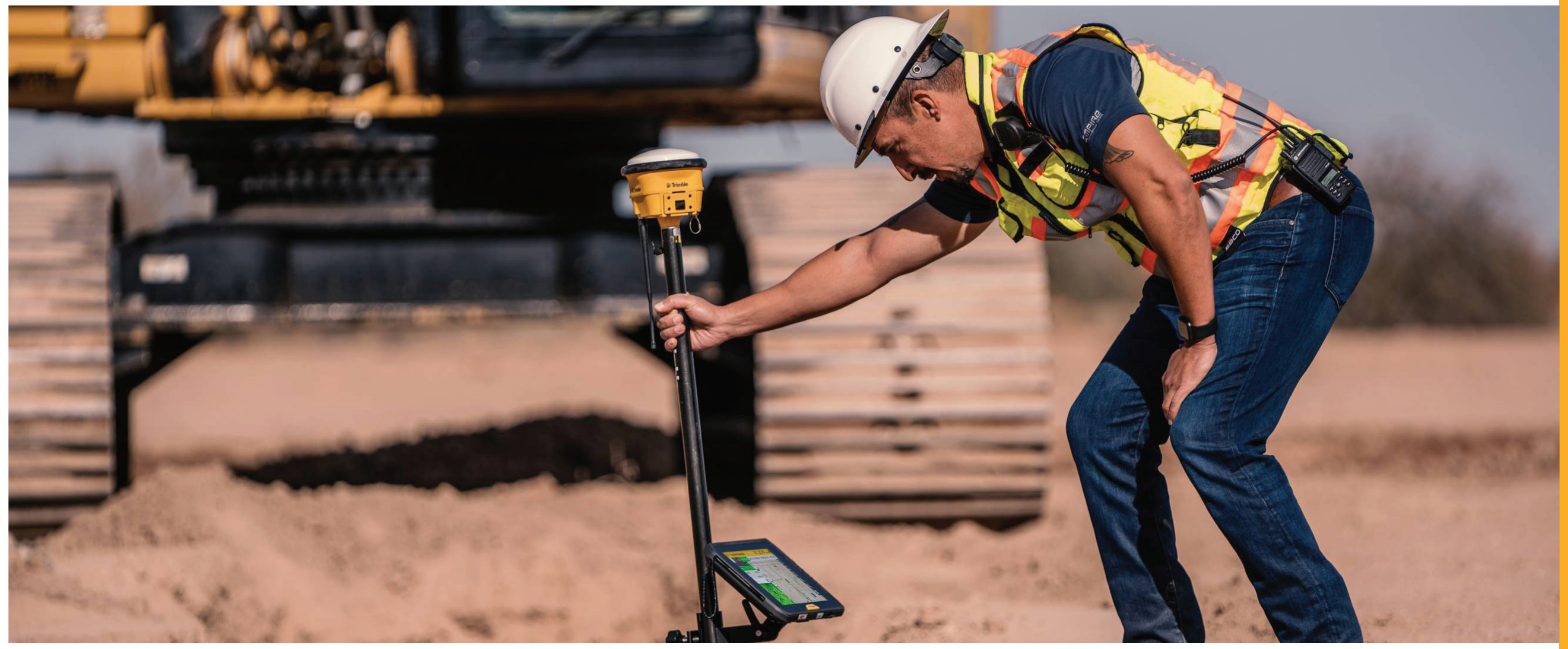
Scanning technology also reduces travel to and from the job site because fewer engineers are needed to perform scans. Laser scanners can be used to capture data throughout the project lifecycle to perform quality assurance and validate whether construction meets design requirements. After construction, they can be used to continuously monitor conditions to determine where improvements can and should be made.

MOBILE MAPPING SYSTEMS

Terrestrial and mobile mapping supports comprehensive street level data capture, which can be used to assess assets for resilience against natural disasters and extreme weather. Governments can identify which structures are most vulnerable in the event of a disaster so they can be flagged for renovation or replacement. And because many sustainability initiatives hinge on transparency, they enable data exchange and standard-setting with other counties, municipalities, and countries.

GIS

Geographic information systems (GIS) are used to gather, manage, and display information about construction assets. With GIS tools, teams can visually manage large amounts of geo-spatial data to view land management projects, streets, buildings, or any other asset. GIS is inherently collaborative, as it leverages data collected from a variety of sources. This provides project stakeholders with the comprehensive data needed to track ecological change, assess cause and effect, and understand the human impact on the environment. With that data, civil planners can reduce environmental consumption and harm by making decisions based on accurate, detailed location-based data.



Download eBook:

3D Scanning Made Simple

Powering Intelligent Public Asset Management with GIS

Infrastructure asset owners have long used their GIS as a repository for current and historical asset data. But many used separate work management systems to manage their assets. Cityworks, a Trimble Company, leverages the ease and flexibility of ArcGIS®, the geodatabase created by Esri®, to create a GIS-centric public asset management platform.

GIS-centric platforms set the foundation for the development of a digital twin, which is a complete virtual representation of an asset. Digital twins combine information about the asset itself, as well as the surrounding environment. And when an asset is outfitted with sensors that collect data on usage, maintenance needs, and other operational information, that information can be stored in the GIS in real-time.

This GIS-centric approach to Cityworks means that infrastructure owners always have access to critical asset data without redundancy, duplication, or syncing. That access and accuracy enables infrastructure and utility owners to optimize performance for sustainability, resilience, and safety.

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Building Management System

Empowers facility managers to manage the myriad of technologies that reduce energy consumption and support grid flexibility

Enables facility managers to monitor sustainability performance in real time and continually identify efficiencies

Supports quick response to maintenance issues, preventing energy losses and equipment failures

Similar to asset management technology, building management systems (BMS) support sustainable operations and maintenance. Because the bulk of energy consumption occurs during a building's operational phase, facility managers face tremendous pressure to continually identify efficiencies. The new breed of high-performing buildings, which incorporate renewable energy resources, grid flexibility, and smart controls, require skillful facility management. BMS systems empower facility managers to manage energy performance and innovative techniques more effectively.

As BMS capabilities expand, facility managers can use them as a home base to control the many systems inside the building. In addition to controlling temperature and lighting, a cloud-based BMS can act as the central hub for collecting data from sensors located throughout the facility. Facility managers and staff can access that data from their desktop, tablet, or mobile phone. Maintenance personnel can quickly respond to service issues, preventing the energy losses caused by faulty equipment and extending the lifespan of critical assets in the process.

A sophisticated BMS with dashboards and reporting enables facility managers to aggregate data to track long-term trends and identify which practices will drive more efficient operations. And if an asset is built following BIM processes, the BMS can leverage the data gathered throughout the construction process to maximize these benefits.

Asset Management Software

Allows for better data collection so owners can prepare for future energy demands and regulations

Empowers owners to make more informed energy management decisions

Enables more effective management of complex utilities and infrastructure systems, ultimately extending the lifespan of assets

Meeting ambitious goals for sustainability requires energy efficiency at scale. By supporting a holistic approach to asset management, asset management technology enables owners to make better operational and energy management decisions.

Complex utilities and infrastructure systems can be managed with integrated technologies to support life cycle modeling and analytics, maintenance scheduling, and real-time reporting, all of which help extend the lifespan of critical assets. Full lifecycle asset management tools also allow for better data collection, so owners can understand and respond to future demands/regulations on energy consumption, resource usage, and waste.

Fleet & Equipment Management System

Allows for real-time asset monitoring to minimize idling, prevent breakdowns, and extend the lifespan of equipment

Optimizes driving routes to avoid congestion and reduce fuel consumption

Acts as a training tool to promote driving habits that improve fuel efficiency

Managing commercial vehicles and equipment is often a reactive process. Although efficiency is always top of mind, the reality can be much different. The assets need to be ready and in place to perform tasks––preventing idle time and conserving fuel are often secondary to those needs. Fleet and equipment management technology helps balance project needs with operational efficiency.

Vehicles and equipment can be outfitted with sensors, known as telematics, that allow operators to proactively monitor usage and maintenance status to minimize idling, prevent breakdowns and use equipment and fleet vehicles for their full useful life. In combination with GPS systems, these tools can be used to optimize routes so vehicles spend less time in traffic.

Telematics also improve efficiency and safety by encouraging better driver behavior. Speeding, hard braking, and quick accelerating are all safety hazards and drains on fuel efficiency. Telematics can track that behavior so that drivers can receive corrective training. They can even provide real-time feedback to drivers in the form of dashboard-mounted alert systems. Being able to consolidate driver behavior, routing, traffic, and other relevant data into a single system allows for broader analysis to drive sustainability across the entire fleet.

Best

Achieving the most ambitious sustainability goals requires the construction industry to push traditional boundaries and incorporate out-of-the-box solutions. Cutting-edge technologies allow construction professionals to completely transform antiquated processes and unlock new capabilities.

These technologies enable AEC firms to improve project efficiency by leaps and bounds and achieve sustainability goals at scale.

Robots

Reliably performs repetitive tasks, reducing errors and waste

Used in 3D printing and prefabrication processes to reduce materials and energy consumption

Can go in places where humans can't without the need for extensive additional resources

There is great potential for robotics in construction, as they have a wide variety of applications throughout the industry. Their ability to reliably perform repetitive tasks reduces errors and waste. They can also perform tasks in areas where humans can't, increasing project efficiency and reducing the time spent using energy-intensive equipment. And artificial intelligence and machine learning enable them to continually improve.

How Robotic Construction Technology is Being Used to Solve Both Present and Persistent Challenges

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Bringing Robotics to the Job Site with Autonomous Scanning

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Robots are already in use across the construction lifecycle, and new projects hold promising potential for the future. Some of the applications for robotics include:

Construction sites produce massive amounts of waste. Sorting robots can efficiently and accurately sift through waste. Using data from 2,280 building demolition projects, researchers trained an algorithm to predict the recoverability of construction waste at 97% accuracy. That algorithm can be used to program robots

3D printing and prefabrication commonly rely on robotics to efficiently create building components. These methods are inherently more sustainable than traditional practices, since a significant portion of construction occurs offsite, where it's easier to control energy efficiency and materials usage

Boston Dynamics' Spot the Robot Dog has been outfitted with a laser scanner to perform positioning data collection. The battery-operated robot can increase the rate of data collection without requiring extensive additional resources

Autonomous (Driverless) Equipment

Holds potential to improve overall job site efficiency by reducing human error

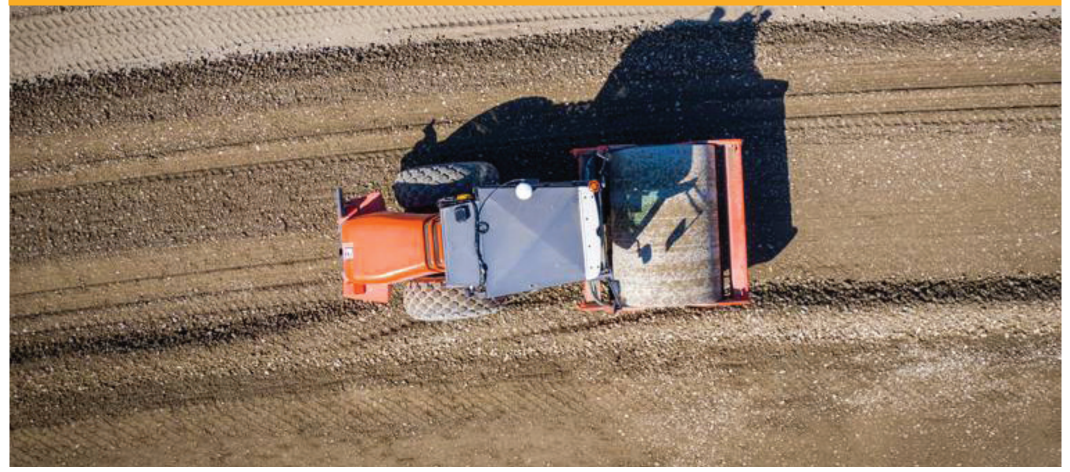
Can be programmed to operate in a way that optimizes fuel consumption

Doesn't require brand new equipment, ultimately preventing waste

Driverless vehicles may not be cropping up left and right. But the technology is becoming more commercially viable, and holds great promise to optimize fuel consumption and improve overall job site efficiency. Existing equipment can be retrofitted with autonomous technology so they can either "drive" themselves or be operated remotely by a human. Existing technologies already in use on construction projects, such as machine control, artificial intelligence, and machine learning, complement autonomous tech and will continue to expand its capabilities.

Programming AVs to prioritize eco-driving, which are practices that reduce fuel consumption, can potentially reduce energy consumption by up to 20%.

SOURCE: UNIVERSITY OF MICHIGAN, AUTONOMOUS VEHICLES FACT SHEET



IoT Sensors

Collects job site and asset data that supports more effective maintenance, reducing wasted materials and fuel

Provides the data needed to support planning for congestion mitigation, water consumption reduction, and other environmental objectives

Automatically reduces energy consumption when an asset isn't in use

Sensors have turned assets of all kinds into smart structures. By continuously collecting data on everything from temperature to occupancy to moisture levels, IoT sensors empower project teams with the actionable data they need to improve sustainability on the job site, and in operations and maintenance.

On the job site, equipment can be outfitted with sensors that constantly collect utilization data that's fed back into fleet and equipment management systems. Contractors can leverage that data to use equipment more efficiently and prevent failures that lead to wasted materials and fuel consumption. During the operations and maintenance phase of an asset, IoT sensors really shine. On roads and bridges, sensors collect real-time data on traffic patterns and parking availability to help with planning congestion mitigation methods.

In buildings, sensors can help monitor energy demand and feed that data to systems that can predict energy consumption and enable smart grid interactivity. Sensors in mechanical, and plumbing systems can alert maintenance personnel when leaks and emerging issues crop up, before they turn into serious problems. And smart lighting systems reduce power consumption by automatically shutting off lights when an area isn't in use.

With this data, operators can track trends across an entire building, campus, or utility system. That allows them to pinpoint long-term energy efficiencies and water reduction strategies.

How IoT Is Making Cities More Sustainable

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Thermal Imaging Technology

Uncovers leaks that cause energy loss, even during construction

Detects moisture in walls, roofs, etc. before it becomes a major issue

Can be used to detect energy losses across a wide area (such as a city block)

Thermal imaging technology detects heat differentials of objects, allowing you to see things that are invisible to the naked eye. Inexpensive, widely available cameras allow builders and maintenance personnel to detect leaks that cause energy loss. Being able to identify leaks during the construction process boost sustainability, since that's the easiest, least resource-intensive opportunity to fix them. For example, when installing a radiant system, contractors can verify that the system is operable and connected before putting additional elements in place.

Thermal imaging can detect moisture in a building's roof, walls, or insulation, as well as plumbing blockages, before they become serious maintenance issues. HVAC leaks, which may be slowly dragging down energy efficiency can be identified early, along with leaks in the roof or the building enclosure. And they don't just show that there is a leak, they enable operators to target the path of the leak and remedy it at the source. To uncover energy losses at scale, thermal imaging cameras can be mounted on drones to take a bird's-eye view of buildings and cities for surveying and inspection.

Why BIM Needs Digital Twins **> GET THE GUIDE**

Digital Twins & Asset Information Models (AIMs)

Empowers operators to identify opportunities to reduce carbon consumption and improve energy management

Contains data collected throughout the construction process, allowing operators to make smarter, less wasteful decisions

Can help contractors manage materials and resources more effectively by incorporating data from IoT sensors

To make significant improvements in energy and resource consumption, and to preserve the lifespan of the built environment, operators are turning to digital twins and asset information models (AIMs). An AIM is the final model produced during a BIM process, and can be used to generate a digital twin. The AIM and digital twin deliver the data maintenance and operations teams need to uncover opportunities for energy, carbon, capital, and operational savings.

Throughout the course of a project, AIMs and digital twins are created with data contributed by various interdisciplinary teams. That data is a gold mine for operators tasked with improving asset sustainability. Before making maintenance decisions or major renovations, owners can know details like asphalt height or the date that a component was installed, allowing them to investigate problems more quickly and use resources wisely.

Because of the proliferation of IoT sensors, digital twins can drive sustainability during the construction process. A digital twin that is continuously updated with data on construction equipment and staffing levels, as well as project progress, can help contractors manage resources more efficiently. And being able to compare the digital twin to the as-designed model allows teams to uncover discrepancies and resolve them in a virtual environment. These capabilities close the communication gaps between many AEC stakeholders, allowing them to prevent waste and rework.

Model-based Estimating & Takeoff

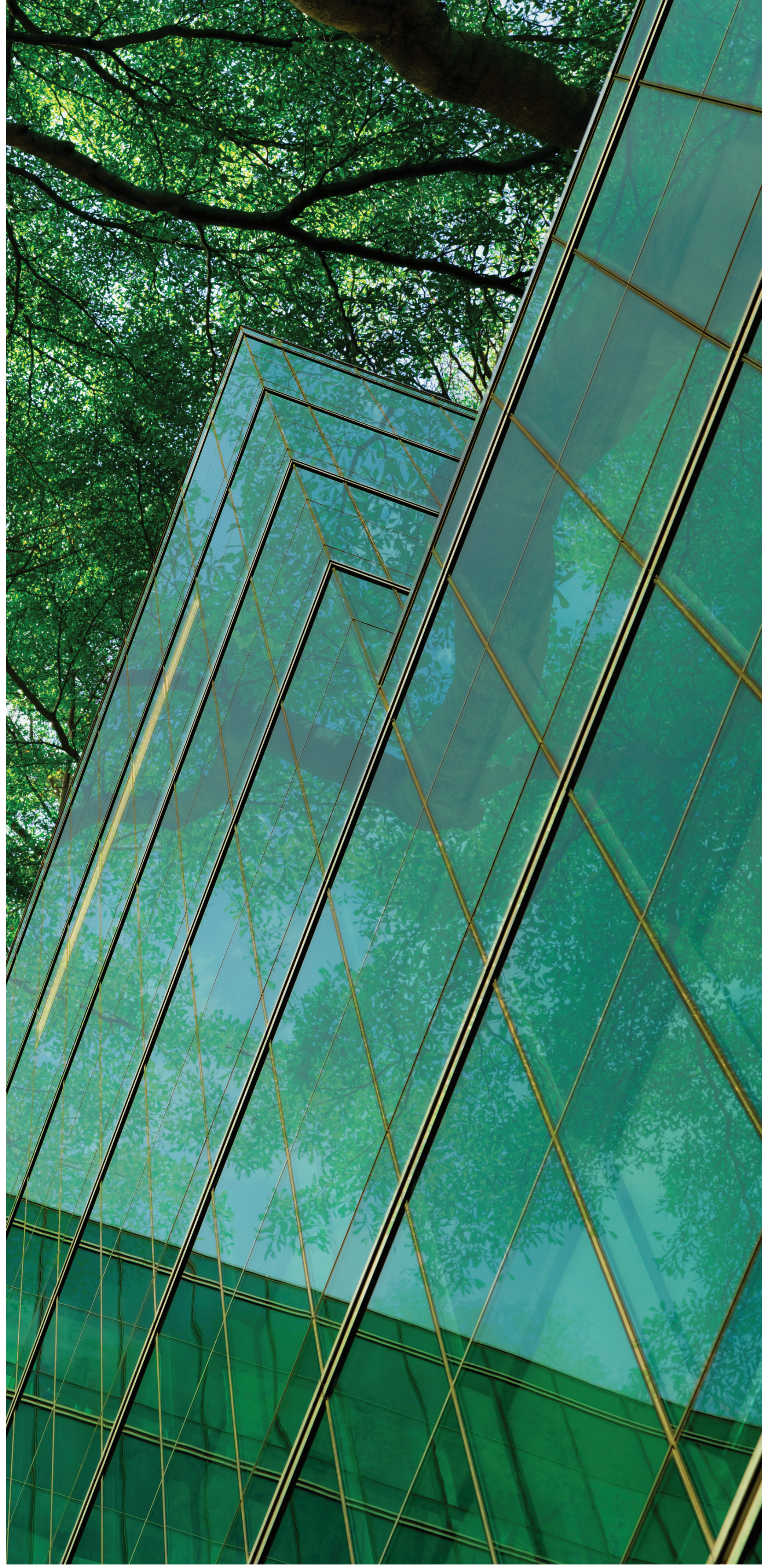
Reduces siloes between project teams, allowing for quicker quantity takeoffs and estimating

Prevents materials waste by improving bid accuracy and project execution

Can update automatically when the model is updated, reducing miscommunication and waste

Much of the waste and inefficiency in construction is caused by disconnected workflows. Model-based estimating tools break down data silos so project teams can perform quantity takeoffs and generate cost estimates more quickly. It also reduces materials waste by improving the accuracy of bids and overall project execution.

Since workflows are all anchored to a model, estimates can be updated automatically when changes are made, reducing the common miscommunications that lead to waste. Leveraging the model for quantity takeoffs and estimates is key to achieving 5D BIM. It can inform pour and formwork planning, scheduling and extraction of quantities for ordering materials, rebar detailing and better overall onsite coordination and collaboration. That data is valuable from the pre-construction phase through operation.



Generative Design

Allows designers to quickly iterate hundreds of sustainable design ideas in a short time frame

Can be combined with 3D printing to explore ideas that aren't possible with traditional construction

Supports designers tasked with increasingly complex sustainability objectives

As the definition of sustainability expands, designers are tasked with solving increasingly complex challenges. With generative design, computers create 3D models based on pre-set parameters. It can produce hundreds of design ideas in a short period of time. Designers can then assess the resulting models, weighing the impact of different material options and energy efficiency measures.

It allows designers to explore new ideas that can improve sustainability throughout the entire construction lifecycle. For example, generative design can sometimes be limited by the shortcomings of traditional construction methods. However, when combined with new technologies like 3D printing, generative design produces building elements that maximize sustainability and meet strict code requirements. For example, using a generative design model produced cantilever beams that could generate between 39% and 51% fewer carbon emissions compared to traditional models.

Read to learn more?

GET YOUR COPY OF THE EBOOK TO KNOW:

- **WHAT'S POSSIBLE WITH CONNECTED CONSTRUCTION**
- **IF YOUR TEAM WOULD BENEFIT FROM CONNECTED CONSTRUCTION**
- **HOW TO GET STARTED WITH CONNECTED CONSTRUCTION**

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Maximizing Technology for Sustainability Starts with Connected Construction

Creating more sustainable assets and reducing construction's impact on the environment are major undertakings. Using environmentally-friendly materials and creating higher-performing assets are one slice of the sustainability pie, but there's so much more.

Construction processes themselves need to be more efficient to cut down on unnecessary waste and emissions throughout the asset's lifecycle.

This requires a shift in mindset, where sustainability is integrated into day-to-day workflows as well as broader initiatives aimed at achieving long-term goals. The right technology can help facilitate that change. Every construction company has access to technology today that can help them reduce carbon emissions and materials consumption, as well as increase collaboration and minimize inefficiencies.

These tools can be used to support larger objectives that help your teams and the industry as a whole set benchmarks, analyze solutions, and track progress. But none of these technologies operate best in a vacuum. As this guide shows, collaboration is essential to using technology to improve construction sustainability.

With better collaboration, projects are executed more efficiently, and construction stakeholders can work together to identify sustainable solutions and monitor their effectiveness. That's why connected construction is so important to the future of construction and protecting our planet.

Connected construction may seem like a lofty goal. But it's best thought of as an ongoing practice rather than a final state. By gaining a more holistic understanding of sustainability and the technologies you can use to address age-old construction problems, you're already ahead of the game. Start where you are, with the tools that set you up to break down silos between teams, and continue to build from there.

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