# Maximizing the Return on Energy Management Investments

Why BIM-based Energy Modelling is a superior—and cost-effective—alternative to benchmarking and energy audits

# Table of Contents


Executive Summary ........ 3

Introduction ........ 4

- Energy efficiency is about more than operational savings ........ 4
- Getting started with energy efficiency upgrades ........ 4

Which Approach is Best? ........ 6

- A framework for comparing options ........ 6
- Understanding a building's energy usage ........ 6
  - Buildings use energy for many purposes ........ 7
  - Buildings are complex environments with interdependent systems ........ 7
  - Each building is unique ........ 8
  - "As designed" and "as built" can be very different ........ 9
- Evaluating approaches to energy analysis ........ 9
  - Energy Benchmarking ........ 9
  - Traditional Energy Auditing ........ 9
  - Statistical Energy Auditing ........ 10
  - BIM-based Energy Modelling ........ 11

Conclusions ........ 15

- Whole-building energy analysis from Planit Measuring ........ 15

# Executive Summary

Building owners have many motivations and significant incentives to invest in upgrades that improve energy efficiency:

- Such retrofits improve occupant productivity, increase appeal for renters, and raise resale values—on top of meaningfully lowering operating expenses
- Attracted by the appeal of net-zero emissions initiatives and the potential for large-scale reductions in energy consumption, governments are offering billions of dollars of incentives to partially offset the cost of retrofits

However, determining which upgrades will provide the most significant returns can be difficult. Buildings are complex environments and the systems that consume energy are interdependent.

Plus, buildings change over time and their energy consumption also depends upon use, location, orientation, architecture, construction, and other characteristics.

To transform a forward-thinking vision into a practical reality, owners need more than inspiration and incentives—they require financially feasible tools that convert intelligent ideas into quantifiable solutions.

Several approaches are available to assist building owners in this pursuit:

- **Energy Benchmarking**, in which a building's energy profile is compared to a composite profile of other buildings
- **Traditional Energy Auditing**, which gathers building-specific information and enters it into energy modelling software
- **Statistical Energy Auditing**, which replaces the onerous and error-prone manual effort of the traditional audit with statistical representations
- **BIM-based Energy Modelling**, which employs simulation and experimentation in a virtual replica (i.e., a Building Information Model) of the building under study

A number of factors should be considered when deciding upon the right approach, including actionability, accuracy, flexibility, convenience, and affordability. An additional factor—extensibility—also has the potential to significantly increase returns by highly leveraging the work done during the energy retrofit long after the project is complete.

All factors considered, because it generates precise, flexible, adaptable solutions that can be tested and proven before making any potentially costly decisions, BIM-based Energy Modelling demonstrably outperforms the alternatives. However, as the newcomer to the field, this approach is hindered by potential misconceptions and a lack of familiarity.

The foremost concern is that BIM-based Energy Modelling requires a BIM of the as-built structure. Owners who lack such a BIM can be quick to dismiss this approach. Fortunately, technology now allows onsite BIM generation in a matter of hours.

The secondary concern is price, but the reality is that BIM-based Energy Modelling typically costs less than energy audits—with the added (and enormous) benefit that the BIM created to enable the energy analysis lives on, providing tremendous additional utility over the building's lifetime and possibly even serving as the basis for a digital twin.

# Introduction

In a world of high, rising, and fluctuating energy costs, optimizing energy management has the potential to deliver substantial returns to building owners and operators and to mitigate financial risk over a facility's lifetime.

*"Optimizing energy management has the potential to deliver substantial returns to building owners and operators—and to mitigate financial risk over a facility's lifetime."*

And for those owners and operators looking to reap the rewards of energy upgrades, externalities are aligning: in recent years, technological advancements have converged to make the upgrade process more effective and efficient; at the same time, attracted by the appeal of net-zero emissions initiatives and the potential for large-scale reductions in energy consumption[1], governments are introducing incentives that partially offset the cost of retrofits.

## Energy efficiency is about more than operational savings

While operational savings receive most of the attention, there are other benefits to making buildings more energy efficient, including:

- Increasing worker productivity: physical comfort (e.g., brightness of lighting, amount of glare, temperature, humidity, etc.) can affect worker performance by up to 20% (plus or minus)[2]
- Making a building more attractive for potential tenants: an extensive North American study[3] on office building tenant satisfaction determined that tenants highly value comfort in office buildings; specifically, respondents attributed the highest importance to comfortable air temperature and indoor air quality
- Raising a building's market value: numerous studies show that energy-efficient buildings—in particular those with green certifications—outcompete inefficient buildings in terms of higher rental and sales prices and building occupancy levels

It's no surprise, then, that so many building owners—whether or not they are also operators—are embarking upon an upgrade path.

## Getting started with energy efficiency upgrades

When it comes to determining where to direct investments in energy efficiency upgrades, building owners have a few options.

A common approach is **Energy Benchmarking**. This method uses an energy analysis process called normalizing to build a benchmark based on data samples and energy usage patterns from buildings that are somewhat (although often only superficially) similar to the building under consideration for upgrades. The building's usage patterns are compared against the composite "benchmark" to identify deviations that hint at potential improvements. Energy benchmarking is a coarse approach that suffers from a number of flaws, one of which is that it generally doesn't enable modelling or simulations that can concretely guide potential upgrade paths.

[1] In their **Quadrennial Technology Review**, published in 2015, the United States Department of Energy reported that, "the buildings sector accounts for 76% of electricity use and 40% of all U. S. primary energy use" and added that, "By 2030, building energy use could be cut more than 20% using technologies known to be cost effective today"
[2] See **Windows and Offices: A study of Office Worker Performance and the Indoor Environment** from Heschong Mahone Group Inc
[3] See What Office Tenants Want: 1999 BOMA/ULI Office Tenant Survey Report

For a project of any meaningful scale, **building simulations** are crucial because they enable auditors and other professionals to make observations and predictions; these testable hypotheses lead to much higher-quality recommendations.

Fortunately, several options are available that leverage a model/representation of the building to run simulations and experiments—these options are described in Table 1.

But which approach is the best option for building owners who are considering making investments—potentially very large investments—to improve energy efficiency?

To answer that question, we'll need to dive into things a bit more deeply.

| Approach | Overview |
|---|---|
| Traditional Energy Auditing | Information derived from many sources (e.g., building specs, photographs, architectural blueprints and drawings, lists of construction materials, and other relevant data) is entered into an energy audit software program database, allowing an auditor to create an energy model.<br>Simulation then attempts to mimic the energy behavior of the actual building. |
| Statistical Energy Auditing | Rather than gathering information from many sources—which is time consuming, labor intensive, and error prone—statistical information is used instead.<br>The simulated models generated in this manner are broadly similar to those developed under the traditional approach, allowing a roughly equivalent simulation.<br>The result is largely equivalent to the traditional energy audit, with the relatively small deviations considered an acceptable trade-off because of this approach's higher convenience. |
| BIM-based Energy Modelling | This method starts by replicating the existing building—precisely and accurately—in a virtual environment that leverages Building Information Modelling (BIM). This interactive model is populated with actual real-world energy usage information spanning an entire year.<br>Next, a second model is built based on the optimum energy performance of the building (e.g., all the windows are properly sealed, the power plant is functioning as it should, etc.). This second BIM serves as the ideal energy-efficient model, illustrating what is theoretically achievable for the building under analysis, accounting for localized conditions (e.g., weather, sun path, etc.).<br>Simulations and experimentation in this virtual world provide accurate and actionable insights into the impact—in terms of energy consumption and return on investment (ROI)—of potential upgrade paths. |

**Table 1** — Building owners and operators interested in making upgrades can choose from several modelling-based approaches

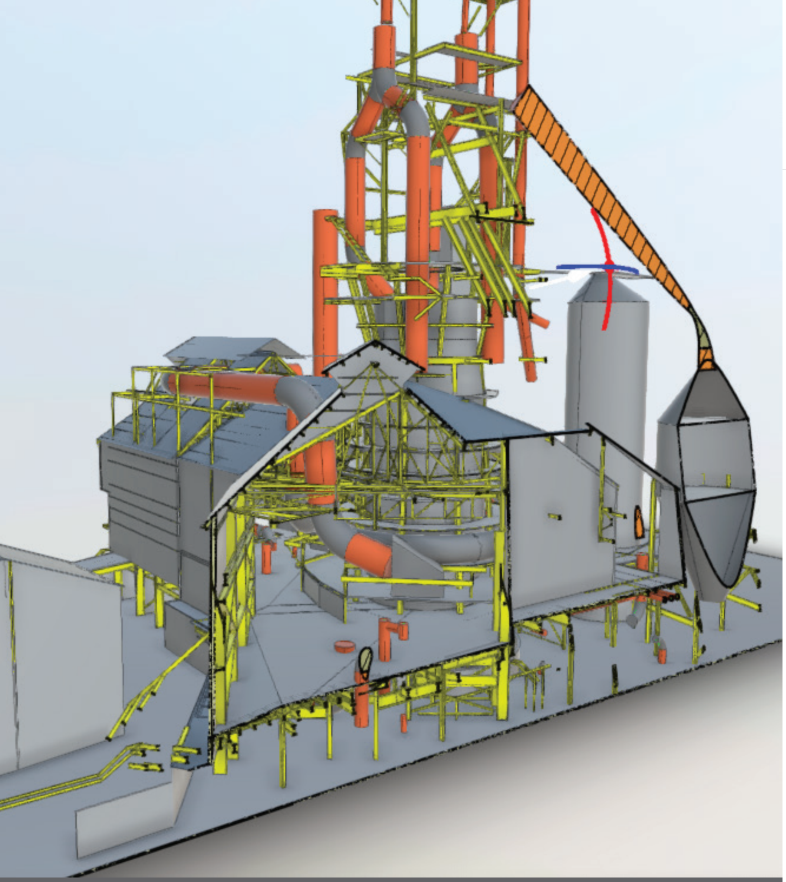

**Figure 1**—Building Information Model of a decades-old steel mill, rendered in Autodesk Revit™

## Building Information Modelling (BIM)

Building Information Modelling is an intelligent, parametric, model-based process that includes the physical and functional characteristics of a facility, providing insights to help with planning, design, construction, and management of buildings and infrastructure.

Within a Building Information Model, nearly every piece of information that an owner needs about a facility throughout its life can be made available electronically.

In the past, such models were only practical when created during the design phase, but technological advances—particularly terrestrial LiDAR scanning—have unlocked the power and potential of BIM for the built world.

# Which Approach is Best?

Optimizing the returns on energy retrofits isn't as simple as improving components and controlling factors that affect them—that's because buildings are complex systems designed to provide occupants with a comfortable, safe, and attractive living and work environment.

*"Buildings are complex systems designed to provide occupants with a comfortable, safe, and attractive living and work environment."*

### A framework for comparing options

To help compare the four alternatives—Energy Benchmarking, Traditional Energy Auditing, Statistical Energy Auditing, and BIM-based Energy Modelling—we need a collection of criteria that captures what matters to building owners and operators (Table 2).

Equipped with these criteria, we are almost ready to evaluate and compare the four options—but before we can do so, it's necessary to examine where energy is used within today's buildings and to explore the factors that impact its usage.

### Understanding a building's energy usage

To find opportunities to improve a building's energy efficiency, we first must understand how buildings put energy to use and recognize that systems within a building do not exist in isolation.

Further, we must appreciate both that every building is unique and that a building as it exists today may be dramatically different from its design or earlier state.

| Consideration | Explanation |
|---|---|
| Actionability | Ultimately, the purpose of an energy assessment is to inform real-world actions by providing clear guidance and cost-based investment paths—the more specific the better |
| Accuracy | For building owners to maximize their ROI and avoid costly mistakes, it's imperative that the insights provided are accurate; of course, these insights are dependent upon the correctness of the baselines, models, simulations, etc. that are employed |
| Flexibility | The richness of the outputs of any simulations and experiments conducted, and the ease or difficulty with which they are able to be conducted, largely depend upon the flexibility of the approach used and the tools it utilizess. |
| Convenience | To be practical in the real world, an approach cannot be terribly time consuming or onerous to conduct |
| Affordability | The total cost—including auditor fees, employee time consumed, etc.—of an approach is obviously a major consideration |
| Extensibility | Looking beyond the energy efficiency initiative, the total value offered by a particular approach is extended—and perhaps even multiplied—if it can be leveraged for other activities; for some building owners this consideration may be a deciding factor, while for others it could have secondary or negligible importance |

**Table 2** — Many factors should be considered when choosing how to embark upon an energy efficiency initiative

### Buildings use energy for many purposes

Figure 2 shows the top six uses of energy within buildings; collectively, these six applications account for nearly two thirds of consumption.[4]

Excluding refrigeration, which is generally outside the scope of a building's efficiency upgrades, the remaining five account for 55.4% of energy usage—hinting at the potential for significant savings.

In each usage category there are opportunities both for improving the performance of system components (e.g., raising the efficiency of lighting devices) and improving the way the components are controlled as a part of integrated building systems (e.g., sensors that adjust light levels to occupancy and daylight)[5].

### Buildings are complex environments with interdependent systems

The relationships between the five major systems—heating, lighting, cooling, water heating, and ventilation—are extraordinarily rich and complex. And complicating matters further, these relationships change with the seasons, with demands placed upon them by the building's tenants, and from place-to-place within a building.

***"Improving a building's energy efficiency necessitates understanding the dynamic interplay between interdependent systems."***

[4] From the Quadrennial Technology Review
[5] For example, Autodesk's **Digital 210 King** project seeks to create a high-quality BIM (in fact, a digital twin) of the company's Toronto office, turning the building into a living laboratory for energy modelling, simulation, validation, and sustainability; this project incorporates sensor-enabled cubicles for occupant-centric capture of building performance data

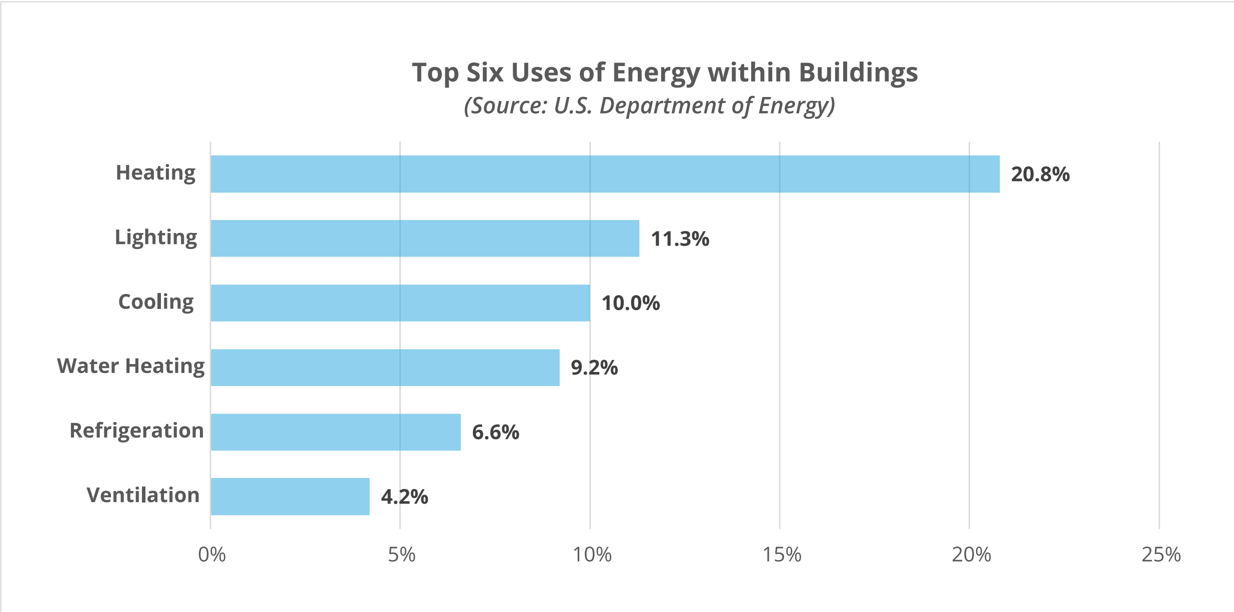


**Figure 2** — These six applications account for nearly two thirds of a building's energy usage

Consequently, improving a building's energy efficiency necessitates understanding the dynamic interplay between interdependent systems.

For example, if a building's lighting system is upgraded from incandescent to fluorescent or LED bulbs, then the electricity used will drop significantly; however, incandescent fixtures release more ambient heat than these energy-efficient alternatives, so removing them will cause the temperature within the building to drop. This drop may lead to higher utilization of the building's heating system during winter months and lower air conditioning expenses in summer months.

### Each building is unique

It's important to note that the usage statistics in Figure 2 represent an average across a diverse spectrum of buildings. In the real world, energy usage varies enormously based upon a building's:

- **Use:** residential, commercial, mixed use; restaurant, manufacturing facility, or office; etc.
- **Location:** latitude, climate, relative to objects providing shade
- **Orientation:** morning, midday, or evening sun
- **Architecture:** layout, shape, size, etc.
- **Construction:** materials used, quality of work
- **Operations:** heating and lighting patterns, occupancy schedules

These factors and other specific characteristics should all be incorporated into the planning that precedes and directs investments in energy efficiency.

> ***"The 'as-built' state in which a building exists today may vary significantly from how it was designed"***

### "As designed" and "as built" can be very different

Even for relatively new constructions—but especially for older facilities—the "as-built" state in which a building exists today may vary significantly from how it was designed, and these variations can exert significant influence on a building's energy efficiency or lack thereof.

As just a few examples, during the life of a building the floor plan may change, insulation may deteriorate or be removed, windows may be replaced, seals may break, and so on.

These changes mean that, over time, the building's original designs become increasingly outdated. In the context of energy modelling, the existing designs and documentation may unintentionally introduce into the analysis significant errors.

## Evaluating approaches to energy analysis

With a more complete understanding of the factors that impact energy usage, we are now ready to examine each of the available approaches and to evaluate them against the factors outlined in Table 2.

### Energy Benchmarking

As noted already, energy benchmarking is a simplistic approach that suffers from a number of flaws; these may be tolerable if the results were worthwhile, but unfortunately that isn't the case.

Fundamentally, the two most significant problems with energy benchmarking are that:

- **It isn't accurate**, since it does very little to account for the properties of the specific building under consideration
- **It isn't actionable**, because simply learning that a building is underperforming relative to others (even in the rare instance that they provide representative comparisons) does little to guide specific corrective actions

| Energy Benchmarking | |
|---|---|
| Actionability | Low |
| Accuracy | Low |
| Flexibility | Low |
| Convenience | High |
| Affordability | High |
| Extensibility | --- |

**Table 3** — Energy Benchmarking is convenient and affordable, but offers little practical utility

Because energy efficiency retrofitting/upgrading isn't a one-size-fits-all proposition, it's necessary to employ a more building-specific methodology—which brings us to energy auditing approaches.

### Traditional Energy Auditing

The traditional energy audit is hugely dependent upon information derived from many sources; this information is entered into specialized software to create an energy model, which permits a moderate degree of simulation and experimentation.

This approach is more accurate and actionable than energy benchmarking, and also involves the use of a model that can be modified, making it moderately flexible.

However, the process of gathering hundreds or thousands of pieces of pertinent information and entering them into the modelling software is labor intensive and prone to human error, which is why statistical energy audits are favored over this traditional approach.

| Traditional Energy Auditing | |
|---|---|
| Actionability | Moderate |
| Accuracy | Moderate |
| Flexibility | Moderate |
| Convenience | Low |
| Affordability | Low |
| Extensibility | --- |

**Table 4** — Traditional Energy Auditing offers more actionability, accuracy, and flexibility than energy benchmarks, but are more cumbersome to execute and incur significantly higher cost

### Statistical Energy Auditing

This approach substitutes the information collected by manual effort with statistical information that most closely matches the building's known characteristics and with data that can be directly imported into and understood by the assessment software.

The primary advantage of this approach is that the model of an existing building can be created and an energy audit can be conducted in considerably less time and with much greater ease than the traditional approach to energy audits. Plus, there are techniques that can accelerate the process—albeit at the expense of accuracy—if the trade-offs are deemed acceptable. For instance, a statistical energy audit might use the average lighting schedule for a building as a reasonable approximation, instead of attempting to customize the model by incorporating the unique usage patterns of each floor or of each individual office or apartment unit.

However, there are drawbacks: fundamentally, the accuracy of the statistical energy audit will vary and the results may be too generic and unrealistic, with particularly unique buildings suffering the most because they aren't well represented by averages.

Additionally, misinterpretations of building geometry within the simulation are not uncommon, as AutoCAD-formatted data is transferred to the energy model software. For instance, the system may not recognize the difference between a window and a rectangular acoustic dampener affixed to a wall.

Also, a common complaint is that once the baseline statistics are input and the parameters are set, revisions to the energy model are cumbersome, labor intensive, and sometimes impossible to achieve to satisfaction without starting over with a fresh model of the updated structure.

Another problem frequently encountered is that there may be several different building plans, owing to the number of contractors, designers, and engineers involved in a project. Even discrepancies that have negligible impact in isolation can quickly compound, further compromising the accuracy and reliability of the audit results.

| Statistical Energy Auditing | |
|---|---|
| Actionability | Moderate |
| Accuracy | Moderate |
| Flexibility | Moderate |
| Convenience | Moderate |
| Affordability | Low |
| Extensibility | --- |

**Table 5** — Statistical Energy Auditing offers the same actionability, accuracy, and flexibility as traditional energy audits, but at higher convenience (and similar relatively low affordability)

### BIM-based Energy Modelling

Addressing the issues encountered with previous methods, parametric or interactive Building Information Modelling technology has been adapted to integrate with energy audit software applications. The BIM energy model allows users (whether auditors or building owners) to simulate a building in an interactive and updatable manner that provides greater simplicity, flexibility, and longevity.

*"The BIM incorporates the building's systems and understands both their effects and their interdependencies, so the insights it provides accounts for these complex relationships"*

Crucially, the BIM incorporates the building's systems and understands both their effects and their interdependencies, so the insights it provides account for these complex relationships.

There are several ways to create a BIM—including importing design files (subject to the aforementioned caveats) and using point clouds to measure the "as-built" space—and in practice these techniques are combined to ensure the building's virtual equivalent precisely and accurately represents the real structure.

This interactive model can be populated with the building's actual real-world energy usage information (e.g., hourly usage for an entire year). Because this model and its data come from the existing building—and not a normalized theoretical one—the "as-built" BIM provides an accurate baseline for the actual building it represents.

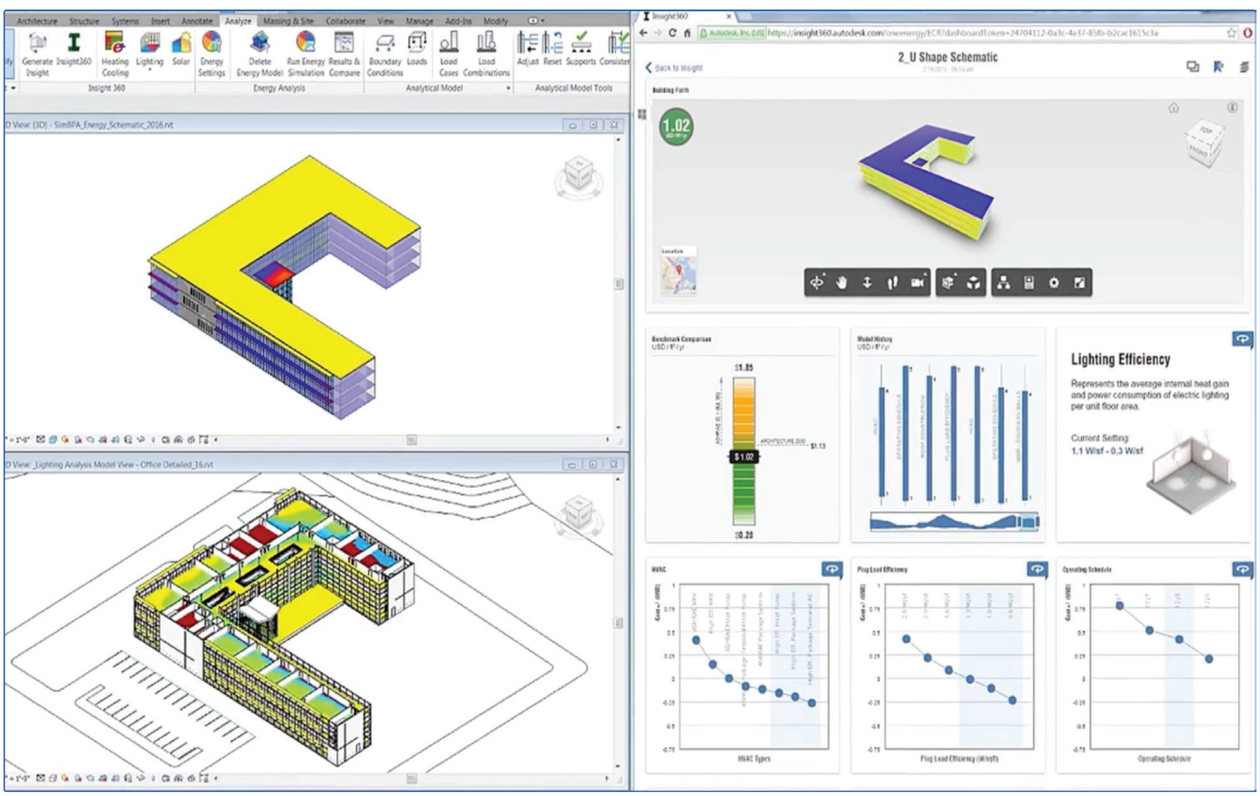


**Figure 3** — BIM software like Autodesk Insight™ faithfully replicates the interrelationship between different building systems[6]

[6] This image is from the Insight overview video at https://www.autodesk.com/products/insight/overview

**Figure 4** — Point clouds make it possible to quickly generate true-to-life ("as-built") BIMs in as little time as a few hours

Next, a second model is built to demonstrate the optimum performance of the building. In this ideal model, for example, all the windows are properly sealed and the power plant is functioning as it should. This BIM showcases the building's peak theoretical performance, accounting for the local factors of its real-world position.

Inputting these two models into whole-building energy software such as EnergyPlus[7] enables accurate and precise simulations that incorporate factors including local weather patterns, the cost of fuel, thermal zones, and the impact of solar heat and light upon the building and the comfort of its occupants.

There is no guesswork involving "similar buildings" because the existing building being studied is analyzed only in comparison to itself under various conditions.

And while both the traditional and statistical energy audits rely on models and incorporate simulation, those models are simplistic in comparison to the BIM, which matches the unique characteristics of a particular building. For example, the BIM's thermal zones can be closely matched to the mechanically designed HVAC zones, rather than relying upon theoretical thermal zone statistics typical of less-sophisticated energy modelling programs.

The versatility of BIM technology also allows an auditor to integrate any combination of changes or strategies and apply them within a single test or analysis. By contrast, conventional energy audits can only show the result of modifying one component at a time.

These capabilities empower users to experiment with such things as retrofits that are applied to the virtual model in a multitude of combinations and permutations, making it possible to correctly, instantly, and affordably explore modifications and to calculate their impact on the building's

[7] See https://energyplus.net/

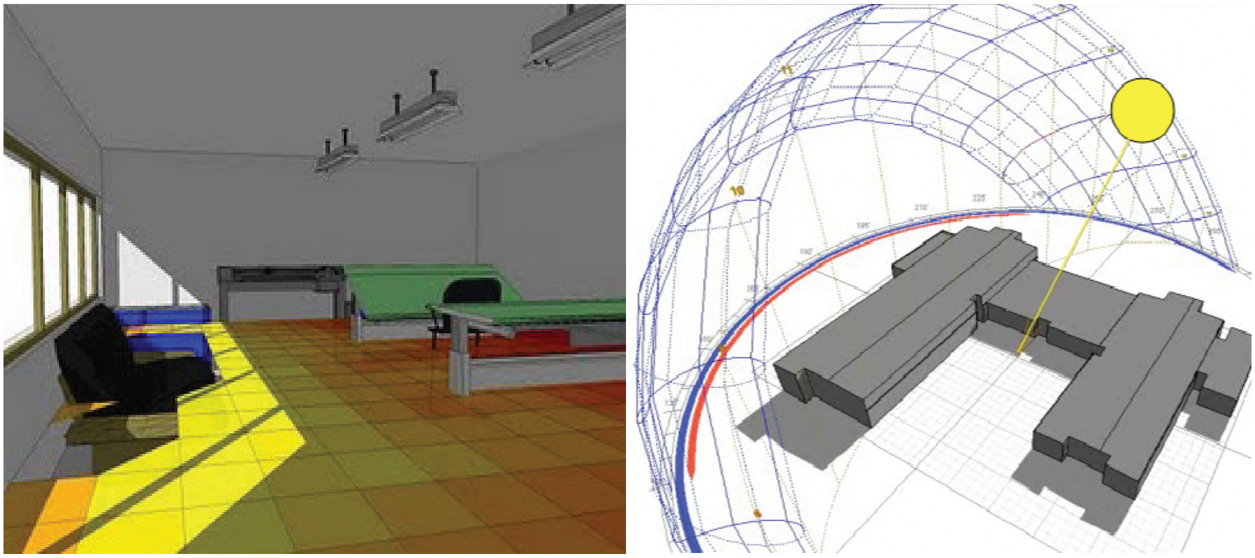

**Figure 5** — Because it can simulate the movement of the sun throughout the year, energy modelling software can assess the impact of solar energy on the building's heating and lighting needs; the same parametric foundation can also be used to calculate the potential returns of introducing solar panels

energy efficiency: from refacing the façade and applying new window film, to adding an insulation jacket and overhauling the ventilation system, it can all be done at the touch of a computer key, with the impact known immediately.

***"The Building Information Model has tremendous utility beyond the energy audit and upgrade initiative."***

Additionally, unlike the approaches explored previously, the Building Information Model has tremendous utility beyond the energy audit and upgrade initiative. Once the BIM is created, it can be leveraged to explore renovations, to equip designers and architectures with true-to-life representations, to create a digital twin, to generate models used for promotional activities (e.g., renderings, virtual walkthroughs, etc.)—and much, much more.[8]

In fact, Building Information Modelling is so useful that the United States General Services Administration (GSA) now requires BIM models on all its building projects.[9]

Importantly, the BIM is easy to update over time: architects, engineers and contractors can add their work to the same database and model file, preventing design conflicts between groups while tracking an unlimited number of modifications. When alterations are made in one part of the BIM, the implications are visible throughout and interrelated changes are made everywhere else in the model. All data and drawing information is associated and linked, virtually ensuring flawless coordination.

[8] For example, the steel mill BIM shown in Figure 1 was created to aid with demolition planning of this complicated structure
[9] To determine the effectiveness of BIM, the GSA initially tested it with a two-year pilot program—the cost savings on just one of the pilot projects was so great that it essentially paid for the entire nine-project program

In this manner, the BIM becomes a "living document" that updates as the building changes, making it useful for the entire life of a building and exponentially increasing the potential returns on the initial investment.

Finally, creating a BIM and conducting BIM-based whole-building energy modelling is not only cost effective, but also highly affordable—costing significantly less than energy audits.

| BIM-based Energy Modelling | |
|---|---|
| Actionability | High |
| Accuracy | High |
| Flexibility | High |
| Convenience | High |
| Affordability | High |
| Extensibility | High |

**Table 6** — The BIM-based approach to energy analysis delivers high marks across the board

## Digital Twins: The Future of BIM and Energy Management

The modern concept of a digital twin is an information model that begins life by representing an asset during design, construction, or as it is built, but is then continuously updated—even in real time—with data to help with a long list of operational and facility management use cases and decisions.

In the most advanced implementations, sensors and feedback loops connect the digital twin to the physical asset, providing exceptional insight and control, while the BIM remains available to assist with simulation and experimentation with a completely up-to-date representation of the building, continually informed by real-world performance data.

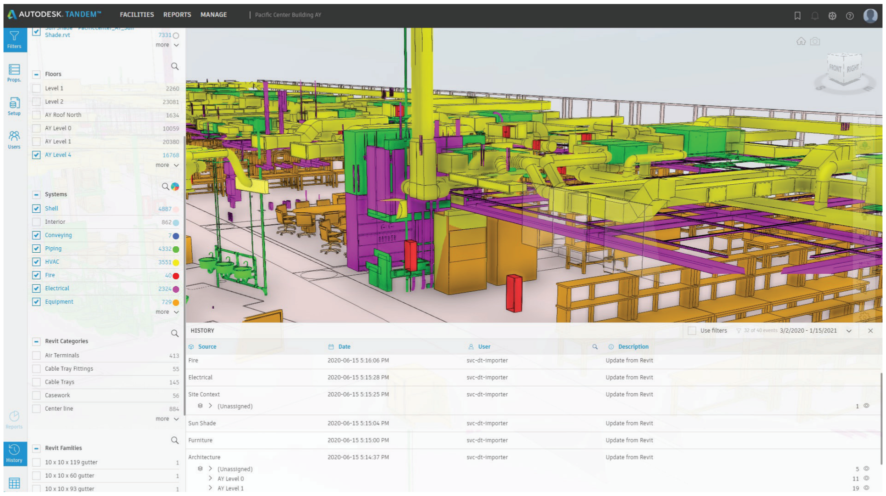


**Figure 6**—In November 2020, Autodesk announced the Autodesk Tandem™ digital twin solution, designed to help project teams create digital twins for handover at project completion; this image is from the **public beta announcement**

# Conclusions

Table 7 distills the preceding analysis and demonstrates that BIM-based Energy Modelling is unquestionably the superior approach to maximizing ROI on energy management investments.

| | Energy Benchmarking | Traditional Energy Auditing | Statistical Energy Auditing | BIM-based Energy Modelling |
|---|---|---|---|---|
| Actionability | Low | Moderate | Moderate | High |
| Accuracy | Low | Moderate | Moderate | High |
| Flexibility | Low | Moderate | Moderate | High |
| Convenience | High | Low | Moderate | High |
| Affordability | High | Low | Low | High |
| Extensibility | None | None | None | High |

**Table 7** — Summary of planning method performance versus assessment criteria

## Whole-building energy analysis from Planit Measuring

Planit Measuring are experts in Building Information Modelling and its many applications—including energy analysis for "as built" structures.

To assist our clients with achieving their energy reduction goals, we are constantly looking for ways to make energy modelling more effective and efficient. To that end, we have:

- Partnered with Bractlet[10]—a leader in building performance optimization—to offer comprehensive BIM-based energy modelling and analysis services
- Performed pioneering work with Autodesk Insight[11]—leading building performance analysis software—to extend the platform's extraordinary utility for the building design phase into the built world

These services enable Planit Measuring to show building owners the impact—in energy usage and dollars—of potential retrofits and upgrades.

Crucially, the analysis doesn't just cover a single year, but incorporates the entire lifetime of the building—providing a comprehensive and accurate view of the potential long-term return on investment.

**To learn more about whole-building energy analysis from Planit Measuring, please reach out to us:**

**Mike Laurie, P.Eng., President**
mike@planitmeasuring.com

**Albert Mansour, VP of Business Development**
albert@planitmeasuring.com

[10] See https://bractlet.com/
[11] See https://www.autodesk.com/products/insight/overview for more information about Autodesk Insight

**ONTARIO**
15 – 225 Speers Rd
Oakville, ON L6K 0J4, Canada

**(905) 271-7010**
**(800) 933-5136**

**NEW YORK**
228 Park Ave S, #28679
New York, NY 10003-1502 USA

**(800) 933-5136**

**www.planitmeasuring.com**