JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A Review paper of Building energy simulation

Bhatt Rudrank Kalpesh[1], Bhaveshkumar K Patel[2]

[1]Student, Department of mechanical engineering, Government engineering college valsad

[2]Assistant professor mechanical engineering, Government engineering college Valsad

ABSTRACT
Residential construction is a very energy-intensive industry. With population expansion and an increase in homeownership, the impact is certain to deteriorate. A wave of green and sustainable initiatives is gaining traction in an attempt to mitigate some of the environment's negative consequences. The building sector is always developing toward greater energy efficiency. However, one of the most significant impediments is a lack of information and concern of upfront expenses among contractors, homeowners, and customers alike. The goal of this study is to determine the utility of existing Life Cycle Cost Analysis (LCCA) processes as a tool for evaluating green building strategies by performing energy simulations for various energy saving measures (ECMs). The purpose of this article is to quantify the trade-off between initial expenditure and long-term benefits associated with various energy saving techniques. We built energy simulation models and life cycle cost models. The created models were used to a scenario involving an apartment in a multi-family structure. This study demonstrates that a mix of passive and active energy saving techniques resulted in the lowest total cost of ownership. The findings indicate a 13.5 percent cost savings when a mix of passive design and active methods is used.

Keywords: sustainable, life cycle cost models, Cost Analysis, passive design

1. INTRODUCTION

One of the main causes of the lack of energy-efficient structures is the often unreasonably high expense of installation of modern technology[1]. What is sometimes neglected is the fact that buildings are long-lasting constructions and investments. However, while selecting building systems, decision-makers and stakeholders often consider up-front prices and beginning expenses. What stakeholders should consider when making choices regarding the building's design and systems is the component's life cycle cost. Despite the multiple advantages of lifetime cost analysis, homeowners and developers in the building sector are slow to embrace it[2]. Several causes for this include a lack of trustworthy data, a scarcity of real performance assessments, a lack of knowledge, and ambiguity regarding possible future savings. Additionally, its uptake in the green construction sector, particularly for low-rise residential structures, has been very gradual[3]. There is a need to extend LCCA into the residential sector, where expansion is constrained by inconsistent data and inadequate coordination among stakeholders[4].

Residential and commercial buildings use 70% of all power generated in the United States. There are several ways available to make buildings more environmentally friendly as a result of technological advancements; for this research, energy efficiency would be the key objective. Although it is clearly established and widely known that energy-efficient buildings are cost effective, there is still a dearth of knowledge on the issue[5], [6].

The authors employed Life Cycle Cost Analysis (LCCA) to establish a more economically attractive argument for energy-efficient techniques in construction, LCCA may be used to evaluate design choices for any structure or system during its life, taking into account the costs and savings associated with each option[7]. For example, LCCA may be used to determine if it is more cost effective to replace an older installed air conditioning system with a new one or to install a central cooling system. Using LCCA to assist in decision-making benefits all stakeholders. Homeowners interested in implementing energy conservation techniques may determine the economic viability of their investment[8]. Taking into account the many alternatives, homeowners may make educated selections that take into account the systems' life cycle performance. The USGBC's Leadership in Energy and Environmental Design (LEED) green building certification programme is dedicated to transforming the way our buildings and communities are designed, constructed, and operated, resulting in an environmentally and socially responsible, healthy, and prosperous environment. improves the quality of life[9]. Clients that use methods like LCCA are given a further score in their LEED rankings by the USGBC. They could potentially be necessary in future in order for the USGBC certification procedure[10]. The trade-off between increased building costs and long-term benefits to the end user is better understood by contractors. In projects including Leadership in Energy and Environmental Design (LEED), life cycle cost analysis is most often used (38%). However, residential (7%), was the sector where the life cycle cost analysis (LCCA) technique was least applicable. Furthermore, a paucity of study has been noted by Islam, Jollands, Setunge, and Bhuiyan (2015) in regards to the assessment of residential building design using life cycle costing (LCC) and life cycle analysis (LCA) techniques[11], [12]. Furthermore, Morrissey and Horne (2011) noted the research void on the incorporation of energy efficiency and economic analyses in the design stage. Decision-makers may use research in this area to obtain quantitative standards for assessing zero-energy residential constructions. Furthermore, there is a dearth of research on the assessment of residential building design using life cycle analysis (LCA) and life cycle costing (LCC) methods. Additionally, there is a research vacuum on the incorporation of energy efficiency and economic analyses in the design stage[13]. Decision-makers may use the quantitative criteria developed by this area of study to assess zero-energy residential structures. Through the use of energy use simulations for various strategies, this study aims to investigate the potential of existing Life Cycle Cost Analysis (LCCA) techniques as an assessment tool for developing energy-related strategies. Additionally, it will look to provide recommendations on how to enhance its uptake for residential structures[14].

2. HISTORICAL CONTEXT

As a developed nation, the United States consumes a lot of energy to support the needs of its population. The industrial, transportation, residential, commercial, and electric power sectors are the five main energy-consuming sectors, according to the US Energy Information Administration (EIA). In an effort to make things simpler, the writers combined the commercial and residential sectors into the "buildings" sector and left out the electric power sector, which deals with the energy required to produce electricity. Next, as Fig. 1 illustrates, the proportion

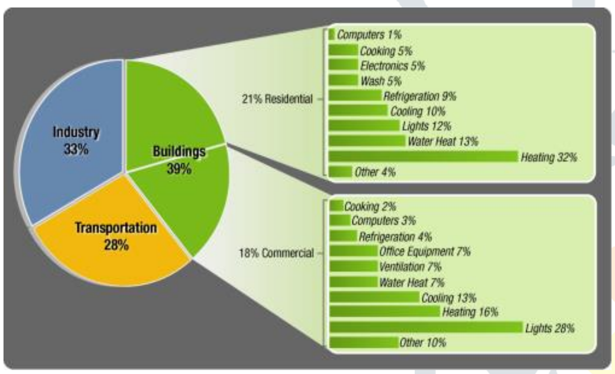

Fig. 1. Building energy consumption

of energy used by end-use sectors in the United States would be as follows (Dwaikat & Ali, 2018b).

The sector that uses the most energy is construction. Construction is responsible for 40–50% of the emission of greenhouse gases and 30–40% of the world's main energy use. They emphasise that "achieving equitable change in humanity" is "critical" thinking for the sector and issue a call to action in closing. Further research confirms these feelings by recognising the growing awareness of the need of energy conservation and how it manifests in the present architecture of buildings. Research studies have been conducted to identify the relationships and tangible (like budget) and intangible (like conflict of interest, expertise, experience, sense of ownership, and occupant input) factors that affect the integrated design process for net-zero energy buildings. Furthermore, research has been done on how climate change affects renewable energy systems intended for zero-energy buildings. Compliance with new regulations mandating more efficiency is required for newly constructed structures. Among the most well-known groups that provide regulations for sustainable construction are the Leadership in Energy and Environmental Design (LEED) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHREA). By 2030, zero net energy buildings must be built, according to the US US Department of the Environment, the Energies Independence and Security Act of 2007, with the American Federation of Architects. With passive design and energy-efficient technology, this behaviour seems to be possible.

There are currently very few buildings that are net-zero-energy (NZEB) in the world, which shows how challenging it has been to develop, construct, and maintain these buildings for a number of reasons. We might conclude that there are still significant restrictions on the energy efficiency of the construction sector. Several of the main reasons for this include the following:

1 A lack of public policies promoting energy efficiency strategies (Ryghaug & Srensen, 2009);
2 Inadequate or non-existent government efforts to regulate green building and the construction industry (Ryghaug & Srensen, 2009);
3 A rigid and conservative construction industry (Ryghaug & Srensen, 2009);
4 A lack of knowledge of new technologies among stalk holders (Shankar Kshirsagar, El-Gafy (Butera, 2013).

2.1. Consumption of energy in residential buildings

Out of all enduse sectors, the building industry uses the most energy (38 percent). It indicates that households make up around 55% of the overall energy used by the building sector, with commercial as well as residential structures accounting for 18% and 20% of the overall energy use by the housing sector, etc[15]. Furthermore, as shown in Fig. 2, the EIA offers a breakdown of the energy consumption of the different installed systems and their parts in houses.

In the home sector, cooling and heating spaces use the greatest energy. 32% of the energy used in American homes was for heating and cooling, according to its most recent Residential Energy Use Survey (RECS) 2015 conducted by the US Energy Information Administration (EIA). But over time, this percentage of energy use has steadily decreased. The increasing use of more contemporary heating systems or better insulation may help to explain this trend. Even with the introduction of better heating and cooling systems, the total amount of energy used has increased due to other modern devices.[16]

In addition, the number of American homes with climate control has been rising, with 87 percent of them having it in 2015.

The researchers predict that home energy usage will continue to rise due to the present level of population rise and the arrival of newer systems for increased indoor comfort, even though the technology used can grow more efficient over time, as in the case of space heating and cooling. Green buildings as well as green buildings.

Graph 1. Shares of total energy consumption in the United States by end-use industry in 2017.

Sustainable Cities and Societies 61 (2020) 102293 A. Hajare and E. Elwakil

Two solutions should be seen as obligatory sustainability measures, not as alternative design approaches.

2.2. Green structures

The idea of green or sustainable construction makes sense given the present energy crisis and the growing conservation movement (Kansal & Kadambari, 2010). As the leading authority on green buildings and sustainable construction practises in the country, the United States Green Building Council (USGBC) defines green buildings as "holistic facilities that leave a beneficial influence on their surroundings via their planning, design, and operation." "Consumes the smallest amount of possible natural resources across its creation and operation with the aim to preserve non-renewable resources" is how a green building is defined (Kansal &

Kadambari, 2010). "It (green construction) additionally supports reuse, recycling, and the use of renewable resources," according to the definition. It ends simply by saying, "A sustainable building method focuses on resource conservation.

"**Passive structures**

Passive design is the most common and widely utilised of the several design approaches used worldwide to develop green buildings. "One that is designed in such a way that an adequate inner environment can be produced without the need of a separate operational heating technology" is the definition of a passive building. Passive buildings may achieve low energy use by regulating heat influx and loss[17], [18].

Zero-energy structures

Equipment and designs that are energy-efficient have been around for a while. But the focus has shifted to creating buildings that use less energy in recent years. "A commercial or residential structure with substantially reduced electricity consumption via" is the definition of a net-zero energy building. These structures are fully powered by renewable energy sources and have extremely good energy performance[19]. The function of zero-energy buildings has been deemed effective as a means of achieving smart cities.

3. METHODOLOGY

A thorough, step-by-step procedure is shown in Fig. 2.

Reducing embodied and operational emissions—that is, emissions produced during the construction and use of buildings—may help to reduce the global warming potential and CO2 emissions associated with the building industry.

reducing building energy use for utilities and thermal comfort requirements. Reduction strategies may be used to achieve this.be integrated into a structure by employing environmentally friendly, highly insulating materials and a highly insulating substance in order to reduce the embodied carbon emissions from the use of bricks from demolition and building materials, plastic bricks, aerated autoclaved blocks, which provide excellent thermal insulation, and expanded clay aggregate blocks, which reduce the high energy consumption from the building's cooling and heating systems. To reduce usefulness Electrical appliances, lights, and home water heating systems may all benefit from improved active technology. a building that uses a range of energy-efficient appliances, solar-powered household water heating systems, and controlled energy-efficient lighting systems, among others. Space conditioning accounts for most of a building's energy use. Interior environment requirements for heating and cooling.

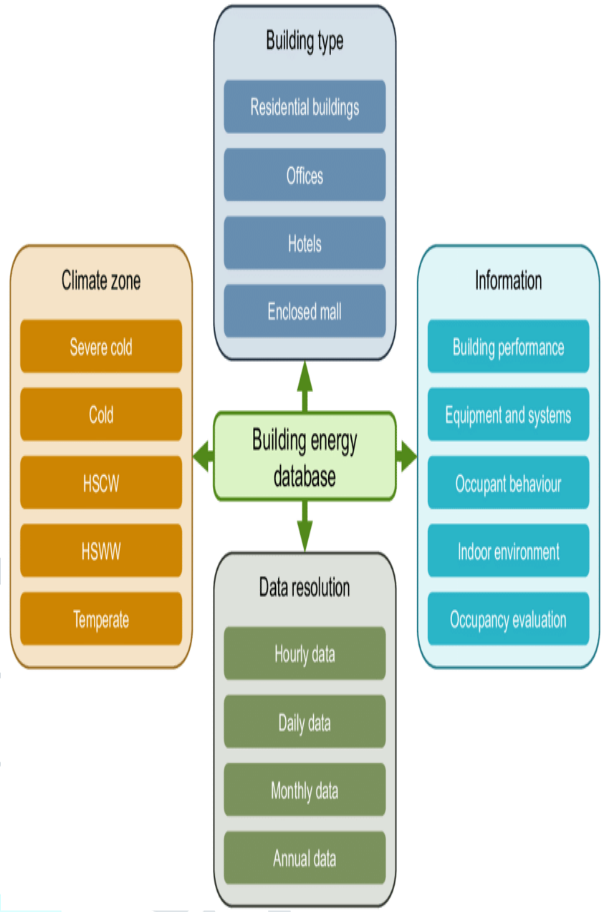

FIG 2 .BUILDING ENERGY DATA COLLECTION METHOD

4. LITERATURE REVIEW

- **Building energy consumption**

1. Md. Jewel Rana, (24 Aug 2020) Impact assessment of window to wall ratio on energy consumption of an office building of subtropical monsoon climatic country Bangladesh

Due to the large amount of solar heat gain that happens via external windows and the high annual average temperature in tropical climates, the window-to-wall ratio (WWR) of a building is an important factor in predicting its energy consumption in these places. This research looks at how WWR affects the amount of energy used in air-conditioned office buildings in Bangladesh, a country with a subtropical monsoon climate. Using the verified energy simulation programme eQUEST, a two-story prototype office building was created as part of this study using a rigorous energy modelling viewpoint. In eight main Bangladeshi cities, wall thickness, thermal insulation thickness, shading height, window orientations, and WWR percentages ranging from 10% to 80% were taken into consideration while developing around 216 design choices for simulation. To determine the ideal range of WWR % for the air-conditioned office buildings, a thorough data study was carried out. According to this study, the ideal WWR range for Bangladeshi air-conditioned office buildings is between 30% and 40%. By implementing the ideal amount of WWR, an existing office block was able to save around 9.40 percent of its power use. The results of this study might be included in the Bangladesh National Building Code as energy-efficient designs for office buildings with air conditioning[20].

2. Ayushi Hajare (2020) Integration of life cycle cost analysis and energy simulation for building energy-efficient strategies assessment

The home construction industry uses a lot of energy. The impact will inevitably become greater as the population grows and the number of homes increases. In an effort to mitigate some of the negative impacts on the environment, a wave of environmentally friendly and sustainable techniques is emerging. Energy consciousness is a constant evolution in the building sector. However, among contractors, homeowners, and customers alike, one of the largest challenges is a lack of knowledge and a fear of upfront expenditures. Through the use of energy simulations for various energy conservation measures (ECMs), this study aims to investigate the potential of existing Life Cycle Cost Analysis (LCCA) techniques as an assessment tool for green construction initiatives. The purpose of this article is to determine how various energy-saving strategies trade off short- and long-term gains. Models for life cycle costs and energy simulation were created. The created models were used on an apartment situation in a multi-family structure. This study demonstrates that the lowest lifespan cost is achieved by combining active and passive energy saving techniques. The findings demonstrate a 13.5% reduction in construction costs when passive design and active techniques are combined[21].

3. Lohit Saini (2021) Net Zero Energy Consumption building in India: An overview and initiative toward sustainable future

The need to switch from fossil fuels to environmentally benign power sources—which may help lessen the effects of climate change and global warming—is driven by the construction sector's increasing need for energy. Making the transition to energy-efficient structures for a sustainable future is one of the efforts to reduce peak load and energy demand in buildings. The purpose of this work is to discuss the essential elements of creating net zero energy consumption buildings (nZECB), taking into account the effects of building physics, the difficulties encountered along the road, and the viability of the strategy. It also discusses some programmes and policies that have the potential to significantly alter the course of emerging countries like India towards an energy system with no emissions in the future. In light of all the information, this research recommends expanding our attention beyond the usage of direct energy, choosing hybridised clean energy sources, and improving the constructional characteristics in order to create a better, cleaner, and greener future[22].

4. Gaurav Singh (2019) Comparative assessment of different air-conditioning systems for nearly/net zero-energy buildings

This research examines how various air conditioning techniques work in a medium-sized building with varying climatic variables in order to reach the goal of nearly/net zero energy. In particular, emissions from renewable energy resources and electricity generated by solar photovoltaic (PV) systems are used to analyse the vapour compression (VC), vapour absorption (VA), and integration of radiant cooling technology. Four types of air-conditioning configurations are taken into consideration: VA-based, VC-based, VC-radiant, and VA radiant air-conditioning with VC-DOAS (Victory-Dedicated Outdoor Air System). For VC- and VA-based systems, numerical model validations using benchmark standards are carried out. In specifically, the following are studied: yearly power consumption, electricity production, generation of thermal load in all configurations, emissions, and solar portion. The current research demonstrates that, under hot dry and composite (i.e., hot dry with greater humidity) climate conditions, radiant VC-based systems with VC-DOAS may effectively meet the goal of nearly/net zero-energy buildings. Achieving total net zero in a warm, humid environment is not feasible, however VC-based radiant and DOAS can guarantee up to 74% of the net zero aim. The most appropriate nearly/net zero building cooling system has a payback time evaluation that, depending on the climatic circumstances, ranges from 5 to 9 years in comparison to the typical VC-based system[23].

5. Altamash Ahmad Baig (2020) Natural gas engine driven heat pump system – a case study of an office building

A Woodstock, Ontario, Canada office building's gas-powered engine-driven heat pump (GEHP) was simulated using an eQUEST model. Before the GEHP was installed, the office building relied on roofing units (RTUs) with an energy-efficient refrigeration unit and a gas-powered heater to provide its temperature regulation needs. The energy consumption of the GEHP & RTUs was tracked during the course of each of their individual month of operating. Regression analysis was performed using the combined energy use measurements and weather data. In accordance with ASHRAE Guideline 14-2014, the generated eQUEST models were verified and calibrated with the use of regression analysis. Woodstock, along with other Canadian towns, especially in Ontario, may realise reductions in yearly energy usage, emissions of greenhouse gases, and cost of power using the fully operational models[24].

6. Daniel Coakley (2014) a review of methods to match building energy simulation models to measured data

Using comprehensive building energy simulation (BES) models is a huge help in the design and optimisation of buildings. In the design phase, simulation models may be used to compare the relative costs of various energy-conservation measures (ECMs), and in the operation phase, they can be used to assess the relative efficacy of various performance optimisation strategies. While a realistic model of real-world building processes is desirable, it is difficult to produce one due to the nature of the physical structure and the existence of many independent conflicting elements. As a result, if we weigh model outputs against observable facts, we could arrive at more accurate and reliable judgements. To calibrate, one must compare seen data with predicted results. This study provides a comprehensive examination of current approaches for model construction and calibration, with a focus on the role of the unknown in the process. In addition, the different analytical and mathematical/statistical tools utilised by practitioners so far are critically examined, and the benefits and limitations of the proposed techniques are discussed[25].

7. Drury B. Crawley (2001) Energy Plus: creating a new-generation building energy simulation program

Some of the most widely used building energy modelling programmes in the world are now in their mature stages, and they use simulation approaches (and even code) that date back to the 1960s. Two hourly building energy simulation programmes (BLAST and DOE-2) were developed with funding from the United States government that spanned over two decades. Because they were created in the era of mainframe computers, adding new features to them is complex, time-consuming, and costly. However, significant improvements in analytical and computing techniques and power have been made over the last 30 years, opening the door to significant advancements in these technologies. The United States federal government started working on a new energy modelling tool for buildings in 1996 called Energy Plus. Energy Plus's input-output data structures are designed to facilitate the development of third party modules and interfaces, and the software features novel simulation features like variable time steps and user-censurable modular architectures that work in tandem with a mass and temperature balance-based zone simulation. Multicolored airflow, power generation, and thermal energy production and photoelectric modelling are all on the list of upcoming capabilities. Energy Plus entered beta testing in late 1999, and its ®rest release is planned for the beginning of 2001[26].

8. V.S.K.V. Harish (2015) A review on modeling and simulation of building energy systems

About 40% of global energy usage goes towards powering buildings, making them a major contributor to greenhouse gas emissions. Efforts to minimise this proportion of CO2 emissions via energy efficiency and conservation have been ongoing over the last decade. Energy modelling and control are now being researched and developed by scientists all around the globe in an effort to reduce the global demand for energy. A computational effective power model of the building under consideration is required for the development of control techniques. All the major modelling approaches that have been established and utilised to simulate building energy systems are discussed in this study. The works themselves are the primary emphasis, since they required the creation of control techniques via the modelling of energy systems in the building. The examined models are organised into several sections, each of which corresponds to a certain modelling strategy. Software and simulation programmes that may be used to model the energy efficiency of buildings are also introduced[27].

9. C. Bussar (2015) Large-scale Integration of Renewable Energies and Impact on Storage Demand in a European Renewable Power System of 2050

Nearly 100 gigawatts (GW) of photovoltaic (PV) systems and more than 100 GW of wind turbines (WT) have been incorporated into the European power grid as of today (2014), driven by falling costs for PV systems and incentive programmes of various governments. In certain regions, power production already surpasses demand, straining the capacity of the current transport system during peak times. To meet the 2050 goals set by the European Commission, system integration will need flexibility sources that are not tied to conventional generation at some time. Adaptability comes from a number of different places. Together, these sources of adaptability will guarantee that supply and demand are always balanced. This adaptability may be provided by energy storage systems via time-based load shifting, and by transmission grids through spatial-based load shifting. Storage may alleviate local peaks in demand and/or generation, which in turn reduces the burden on transmission systems, but only up to a point. Significant upgrades to the power grid's infrastructure are needed to complete the switch to renewable energy sources by 2050. The GENESYS simulation programme takes a comprehensive view of the European power system, allowing users to make informed decisions on the optimal allocation and scale of various generating technologies, storage systems, and transnational networks. The simulation tool's source code is freely downloadable thanks to a public licence. Because it is highly configurable, it may be used to examine many electrical systems under a variety of assumptions about demand, generating potential, and cost structure of the various system components. The simulation environment, the model of the system, and the optimisation approach will all be presented in this paper. GENESYS optimisation findings for a 2050 cost structure for a renewable power system[28].

10. K.J. Lomas (1997) Empirical validation of building energy simulation programs

Recently, the world's biggest test of dynamic thermal simulation programmes (DSPs) for buildings was conducted. It contained both commercial and public domain software and included 25 different user/program combinations from Europe, the United States, and Australia. Three UK test rooms with a single environmental zone have predictions made for them. All of them faced south and either featured a single- or double-paned window. The rooms were heated on and off for ten days during one cycle, and for the same amount of time during the other cycle. We compared the predicted heating energy requirements and air temperatures. Rather than changes in implementation, it seemed probable that differences in the DSPs themselves were responsible for the observed interprogram heterogeneity. There was no more consistency when attempting to anticipate the relative performance of two separate areas than there was when attempting to predict the absolute success of a single room. DSPs that are expected to have major internal errors are separated from those that did significantly better in these tests by comparing the predictions with what was observed and taking adequate account of experimental uncertainty. Internal error sources are explored. A blind phase, when programme users don't know actual test results of the creating, is advised for empirical validation activities, followed by an open phase, where the findings are made accessible. Five empirical validation standards have been developed as a result of this effort, which will be very useful to programme users, suppliers, and prospective buyers. Suggestions for future work are suggested, since there is a lot of room for increasing DSPs' predictive capacity[29].

11. Michael J. Witte (2001) testing and validation of a new building energy simulation program

Energy Plus is a novel energy modelling programme, and its development has been heavily based on formal independent testing. Too far, we have conducted a wide variety of tests, including analytical, comparing, awareness, range, and empirical. To take pleasure in the work of others in developing well-defined, repeatable tests, we have relied heavily on existing test suites that provide reference findings. Too far, the findings have been in excellent sync with those obtained using conventional simulation methods as DOE-2.1E, BLAST, and ESP. Several testing applications have been created to automate the process of ensuring that each software update continues to function as expected. We share some of our test findings and what we've learnt from them[30].

12. Zhichao Tian (2018) towards adoption of building energy simulation and optimization for passive building design: A survey and a review

One possible strategy for producing energy-efficient buildings is to include optimisation techniques into simulation-based design procedures. Despite its potential, building energy simulating & optimisation (BESO) is still in its infancy as a design tool. The purpose of this two-part study was to determine the requirements, advantages, and disadvantages of using BESO in sustainable building design, with a focus on passive design. Studying the thoughts of early adopters was given a lot of focus. There are nine possible drawbacks to the BESO approach, but the lengthy calculating time, little advertising, and absence of a uniform method or process are among the most significant. A study was done to classify a standard process for the BESO method based on the poll findings. It was looked at how the BESO method may be used in passive building design. Structures' opaque envelopes, fenestrations, shadings, airflow from nature, and thermally dense materials all played a role in passive design. The research found that the most popular strategy was a three-stage optimisation process. BESO is now proving to be a more successful approach than other passively techniques in assisting designers (particularly architects) in investigating new design frontiers[31].

13. Michael Wetter (2004) Simulation-Based Building Energy Optimization

In order to optimise the design of buildings and HVAC/L systems using simulation, the author of this dissertation proposes computational methodologies for doing so. The assessment of the cost function in such issues requires a numerical interpretation of systems of DAE. A computer code to deal with such systems often specifies a numerical approximating to the cost equation that is discontinuities in the design parameters, since this is required by the termination requirements of the iterative solvers. Optimisation techniques that rely on smoothness often fail when employed with commercial building energy modelling software because the discontinuities in the cost functions assessed by the software might be substantial. Furthermore, commercial building power modelling programmes seldom provide for the management of the numerical approximation 2 inaccuracy. In this thesis, we introduce BuildOpt, a novel programme for simulating the thermal performance of buildings and the effects of daylight. Smoothness in state variables, time, and design parameters are all hallmarks of the DAE system defined by the simulation models provided by BuildOpt. It is necessary to calculate high-precision approximation price functions that converging to a cost function that is smooth in the design settings when the DAE solver tolerance is tightened, and this enables us to prove that the DAE system has a unique solution. We developed auxiliary procedures for Generalised Pattern Search (GPS) optimisation algorithms that adaptively authority the precision of the cost function evaluations, beginning with a coarse precision for the early iterations and gradually increasing to a stationary point, for simulation programmes that permit such a control. Time spent computing is cut drastically, and proof that a pattern of goes includes stable accumulation sites may be established using this method. We analyse different deterministic and probabilistic optimisation techniques for optimisation issues where the cost function is determined by running commercial building energy modelling programmes[32].

14. Monjur Masum Mourshed (2003) Integrating Building Energy Simulation in the design process

To significantly increase building energy performance, the use of building simulation software at the earliest has been emphasized. Inherent complexity in data representation, I/O (Input and Output) and Visualization of available software requires specialist knowledge to leverage the potentials offered. Early stages of design are characterized by unstructured and incomplete data, which is insufficient as inputs to software based on detailed representations of the systems in the building. Existing simulation software, developed in research organizations are targeted to be used by building services engineers at detailed stages and does not suit the purposes of design community. This article attempts at identifying the reasons behind unpopularity of simulation software in the early stages of design and also argues that a new breed of decision support systems is needed for energy efficient building design[33].

15. Leen Peeters (2008) Thermal comfort in residential buildings: Comfort values and scales for building energy simulation

Building Energy Simulation (BES) programs often use conventional thermal comfort theories to make decisions, whilst recent research in the field of thermal comfort clearly shows that important effects are not incorporated. The conventional theories of thermal comfort were set up based on steady state laboratory experiments. This, however, is not representing the real situation in buildings, especially not when focusing on residential buildings. Therefore, in present analysis, recent reviews and adaptations are considered to extract acceptable temperature ranges and comfort scales. They will be defined in an algorithm, easily implementable in any BES code. The focus is on comfortable temperature levels in the room, more than on the detailed temperature distribution within that room[34].

16. J. R. SIMPSON (1997) simulation of tree shade affects residential energy use for space conditioning

Tree shade reduces summer air conditioning demand and increases winter heating load by intercepting solar energy that would otherwise heat the shaded structure. We evaluate the magnitude of these effects here for 254 residential properties participating in a utility sponsored tree-planting program in Sacramento, California. Tree and building characteristics and typical weather data are used to model hourly shading and energy used for space conditioning for each building for a period of one year. There was an average of 3.1 program trees per property which reduced annual and peak (8 h average from one to 9 p.m. Pacific Daylight Time) cooling energy use 153 kWh (7.1%) and 0.08 kW (2.3 %) per tree, respectively. Annual heating load increased 0.85 GJ (0.80 MBtu, 1.9%) per tree. Changes in cooling load were smaller, but percentage changes larger, for newer buildings. Averaged over all homes, annual cooling savings of $15.25 per tree were reduced by a heating penalty of $5.25 per tree, for net savings of $10.00 per tree from shade. We estimate an annual cooling penalty of $2.80 per tree and heating savings of $6.80 per tree from reduced wind speed, for a net savings of $4.00 per tree, and total annual savings of $14.00 per tree ($43.00 per property). Results are found to be consistent with previous simulations and the limited measurements available. Published by Elsevier Science Ltd[35].

17. Venkatesh*, B. Aksanli HomeSim: Comprehensive, Smart, Residential Electrical Energy Simulation and Scheduling

Residential energy constitutes 38% of the total energy consumption in the United States. Although a number of building simulators have been proposed, there are no residential electrical energy simulators capable of modeling complex scenarios and exploring the tradeoffs in home energy management. We propose HomeSim, a residential electrical energy simulation platform that enables investigating the impact of technologies such as renewable energy and different battery types. Additionally, HomeSim allows us to simulate different scenarios including centralized vs. distributed in-home energy storage, intelligent appliance rescheduling, and outage management. Using measured residential data, HomeSim quantifies different benefits for different technologies and scenarios, including up to 50% reduction in grid energy through a combination of distributed batteries and reschedulable appliances[36].

18. Erdal Aydin (2017) The Impact of Policy on Residential Energy Consumption

Due to the growing concerns about global climate change and energy dependence, many countries have introduced regulations targeting the energy efficiency of the residential sector. However, whether these policies have been effective in reducing the total residential consumption of energy is still unclear. In this paper, we analyze the impact of residential energy efficiency policies on household energy consumption across Europe for the period 1980-2009. We examine the electricity and non-electricity energy consumption separately, as these are generally used for different purposes (appliances and heating) by households and are subject to different energy efficiency policies. We focus on two distinct types of regulations mandatory energy efficiency labels for household appliances and building standards. We find that after controlling for the county-specific effects and the changes in income, energy prices, demography and climate conditions over our sample period, both the energy labeling requirements for appliances and the stricter building codes lead up to lower residential energy consumption[37].

19. Elisha R. Frederiks (2015) the Socio-Demographic and Psychological Predictors of Residential Energy Consumption: A Comprehensive Review

This article provides a comprehensive review of theory and research on the individual-level predictors of household energy usage. Drawing on literature from across the social sciences, we examine two broad categories of variables that have been identified as potentially important for explaining variability in energy consumption and conservation: socio-demographic factors (e.g., income, employment status, dwelling type/size, home ownership, household size, stage of family life cycle) and psychological factors (e.g., beliefs and attitudes, motives and intentions, perceived behavioral control, cost-benefit appraisals, personal and social norms). Despite an expanding literature, we find that empirical evidence of the impact of these variables has been far from consistent and conclusive to date. Such inconsistency poses challenges for drawing generalizable conclusions, and underscores the complexity of consumer behavior in this domain. In this article, we propose that a multitude of factors whether directly, indirectly, or in interaction influence how householders consume and conserve energy. Theory, research and practice can be greatly advanced by understanding what these factors are, and how, when, where, why and for whom they operate. We conclude by outlining some important practical implications for policymakers and directions for future research[38].

20. Nikhil Kaza (2010) Understanding the spectrum of residential energy consumption: A quantile regression approach

Residential energy consumption accounts for 22% of the total energy consumption in the US. However, the impacts of local planning policies, such as increasing density and changing the housing type mix, on residential energy consumption are not well understood. Using Residential Energy Consumption Survey Data from the Energy Information Administration, quantile regression analysis was used to tease out the effects of various factors on entire distribution on the energy consumption spectrum instead of focusing on the conditional average. Results show that while housing size matters for space conditioning, housing type has a more nuanced impact. Self-reported neighborhood density does not seem to have any impact on energy use. Furthermore, the effects of these factors at the tails of the energy use distribution are substantially different from the average, in some cases differing by a factor of six. Some, not all, types of multifamily housing offer almost as much savings as reduction in housing area by 100 m2, compared to single family houses[39].

21. M. Deru (2003) Infiltration and Natural Ventilation Model for Whole Building Energy Simulation of Residential Buildings

The infiltration term in the building energy balance equation is one of the least understood and most difficult to model. For many residential buildings, which have an energy performance dominated by the envelope, it can be one of the most important terms. There are numerous airflow models; however, these are not combined with whole-building energy simulation programs that are in common use in North America. This paper describes a simple multitoned nodal airflow model integrated with the SUNREL whole-building energy simulation program. The required inputs for infiltration are taken from blower door test results and the geometry of the openings for natural ventilation. The flow exponents and coefficients for infiltration and natural ventilation can be input or left to the default values. Control of the natural ventilation openings can be controlled with a time scheduled and the indoor/outdoor temperature difference. The mass-flow rate equations are written in terms of the pressure at the base of each zone. The pressure on each surface is a combination of stack and wind effects added to the zone base pressure. The resulting set of mass balance equations are solved using a Newton-Raphson iterative method with a variable relaxation coefficient. The relaxation coefficient is adjusted each iteration depending on the speed of the convergence. The iterations are stopped when the mass balance in each zone converges to a specified tolerance. The model exhibits good numerical behavior, with no singularities and only a few instances of nonconvergence in some building simulations with no thermal mass and large leakage areas. The infiltration model compares favorably to the LBL infiltration model. The natural ventilation model also compares well with another natural ventilation model and with measured results. The current infiltration model and whole-building simulation program form the basis of a new residential energy-auditing tool[40].

22. Ahmad Sabry An-Naggar (2017) Energy Performance Simulation in Residential Buildings

Energy availability in Egypt is one of the major problems that confront the government. Energy consumption in residential buildings is considered the biggest section that consumes electric energy generated by the electric power stations. The continuing increase in the number of residential buildings requires a corresponding increase in the number of power stations in order to meet the increased demand. Unfortunately, such an increase will result in significant depletion of traditional energy resources. With the rising of the energy economic cost, an urgent thought started to reduce the consumption by all possible rationalization and efficient use means. The consumed energy in buildings increases year annually according to several factors, the major ones being the increase of the number of air-conditioners installed, and their operating hours. In the present investigation a residential building is considered to consist of three floors and six apartments of 100-floor area for each apartment; this building has been drawn by software called "Design builder". The present investigation is carried out on the left apartment on the third floor (typical floor) on two cases; one with thermal insulation in the walls and the roof and the other without thermal insulation. The present paper illustrated here, using "Design builder" software, three comparisons between the sensible cooling load, air-conditioner energy consumption rate, cost of the energy consumed and the CO2 produced by power plant, due to the energy consumed on the two cases, at three different room temperatures. The room temperature was set at; 24°C, 22°C and 20°C respectively[41].

23. Yair Schwartz (2013) Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study

The increased awareness of building energy consumption and sustainability has resulted in the development of various means of predicting performance and rating sustainability. The Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) are the most commonly used Performance Rating Systems. To predict energy consumption and award relevant energy performance credits, these systems use computer-based Building Performance Simulation tools (BPS). Predictive inconsistencies between BPS tools have been acknowledged in various studies. The probability of achieving different ratings by using different BPS tools or rating systems raises questions concerning the ability to rate 'sustainability' in a consistent manner. To investigate this, a case-study based inter-model comparative analysis was implemented to examine the extent of the variation in the results produced by three of the most widely used BPS tools (Tas, Energy Plus and IES), and assess their influence and impact on overall BREEAM and LEED scores. Results showed that different simulation tools resulted in different energy consumption figures, but had only a minor effect on BREEAM or LEED energy performance credit scores. Nonetheless, due to the differences between BREEAM and LEED assessment procedures, the case study building was awarded a considerably different rating level in each[42].

24. Tobias Maile (2007) Building Energy Performance Simulation Tools - a Life-Cycle and Interoperable Perspective

Energy simulation tools are increasingly used for analysis of energy performance of buildings and the thermal comfort of their occupants. This paper describes a selection of energy simulation engines and user interfaces that are capable of these analyses today. Specifically, it discusses the usage of these tools over different life-cycle stages. Besides a brief overview about energy simulation concepts, the paper illustrates each tool's strengths and weaknesses as well as its data exchange capabilities. Given the significant variety of such energy simulation tools, it is crucial to understand limitations of the tools and the complexity of such simulations. The reliability of data exchange and straightforward, user-friendly interfaces are major aspects of the practical usage of these tools. Due to the huge amount of input data and the availability of rich 3D geometry models effective data exchange and software, interfaces are crucial to enable faster and more reliable energy performance simulation analysis[43].

25. Mohammad Saffari (2017) passive cooling of buildings with phase change materials using completely building energy simulation tools: A review

Buildings contribute to climate change by consuming a considerable amount of energy to provide thermal comfort for occupants. Cooling energy demands are expected to increase substantially in the world. On this basis, technologies and techniques providing high-energy efficiency in buildings such as passive cooling are highly appreciated. Passive cooling by means of phase change materials (PCM) offers high potential to decrease the cooling energy demand and to improve the indoor comfort condition. However, in order to be appropriately characterized and implemented into the building envelope, the PCM use should be numerically analyzed. Whole-building energy simulation tools can enhance the capability of the engineers and designers to analyze the thermal behavior of PCM-enhanced buildings. In this paper, an extensive review has been made, with regard to whole-building energy simulation for passive cooling, addressing the possibilities of applying different PCM-enhanced components into the building envelope and also the feasibility of PCM passive cooling system under different climate conditions. The application of PCM has not always been as energy beneficial as expected, and actually, its effectiveness is highly dependent on the climatic condition, on the PCM melting temperature and on the occupant's behavior. Therefore, energy simulation of passive PCM systems is found to be a single-objective or multi-objective optimization problem, which requires appropriate mathematical models for energy, and comfort assessment, which should be further investigated. Moreover, further research is required to analyze the influence of natural night ventilation on the cooling performance of PCM[44].

26. Yong K. Cho (2010) BIM-Integrated Sustainable Material and Renewable Energy Simulation

The primary goal of the research is to investigate the discontinuities between current energy modeling tools and the implementation of sustainable features within the models they produce for better envelope design and construction material selection. From previous research efforts, it was discovered that energy modeling has made advances within their integration to early and mid-level design phases, particularly with Building Information Model (BIM) and the Green Build extensible Markup Language (gbXML) file type. However, it was also discovered that BIM-integrated energy modeling tools are often lacking in their ability to incorporate renewable energy sources such as photovoltaic panels, wind turbine, and geothermal wells. This paper introduces strategies to include such sustainable fixtures to predict energy generation with a case study of Zero Net Energy Test Home (ZNETH). In addition, this paper introduces parametric analyses for better envelope design and construction material selection by analyzing simulated energy consumptions with various parametric inputs, e.g., material types, location, and size[45].

27. Li Honglian (2020) Compare several methods of select typical meteorological year for building energy simulation in China

In the early architectural design and energy saving reconstruction of building, it is essential need the typical meteorological year（TMY）for building performance analysis. The accuracy of the typical meteorological year data is directly affecting the energy simulation results. In order to obtain accurate TMY data for construction engineering applications, the paper does the following work: (1) Reviewed the progress of the typical meteorological year; (2) Several TMY generation methods were compared using the same raw weather data, discusses the applicability of these methods for the cities of typical climate zones in China. Based on the most recent and comprehensive first-hand ground observation data, this paper adopts three methods to generate TMY for the typical city covering the climate zoning of China. Result shows different TMY generation method has applicability in different region, and through the simulation of building energy consumption, the comprehensive method has obvious advantages. It shows that in a region with diverse regional climate characteristics such as China, one certain method for selecting TMY is not enough, and comprehensive methods should be proposed to meet the needs of different building types and energy consumption simulation[46].

28. Zeyu Wang (2016) a review of artificial intelligence based building energy use prediction: Contrasting the capabilities of single and ensemble prediction models

Building energy use prediction plays an important role in building energy management and conservation as it can help us to evaluate building energy efficiency, conduct building commissioning, and detect and diagnose building system faults. Building energy prediction can be broadly classified into engineering, Artificial Intelligence (AI) based, and hybrid approaches. While engineering and hybrid approaches use thermodynamic equations to estimate energy use, the AI-based approach uses historical data to predict future energy use under constraints. Owing to the ease of use and adaptability to seek optimal solutions in a rapid manner, the AI-based approach has gained popularity in recent years. For this reason and to discuss recent developments in the AIbased approaches for building energy use prediction, this paper conducts an in-depth review of single AI-based methods such as multiple linear regression, artificial neural networks, and support vector regression, and ensemble prediction method that, by combining multiple single AI-based prediction models improves the prediction accuracy manifold. This paper elaborates the principles, applications, advantages and limitations of these AI-based prediction methods and concludes with a discussion on the future directions of the research on AI-based methods for building energy use prediction[47].

29. Pervez Hameed Shaikh (7 March 2014) A review on optimized control systems for building energy and comfort management of smart sustainable buildings

Buildings all around the world consume a significant amount of energy, which is more or less one-third of the total primary energy resources. This has raised concerns over energy supplies, rapid energy resource depletion, rising building service demands, improved comfort life styles along with the increased time spent in buildings; consequently, this has shown a rising energy demand in the near future. However, contemporary buildings' energy efficiency has been fast tracked solution to cope/limit the rising energy demand of this sector. Building energy efficiency has turned out to be a multi-faceted problem, when provided with the limitation for the satisfaction of the indoor comfort index. However, the comfort level for occupants and their behavior have a significant effect on the energy consumption pattern. It is generally perceived that energy unaware activities can also add one-third to the building's energy performance. Researchers and investigators have been working with this issue for over a decade; yet it remains a challenge. This review paper presents a comprehensive and significant research conducted on state-of-the-art intelligent control systems for energy and comfort management in smart energy buildings (SEB's). It also aims at providing a building research community for better understanding and up-to-date knowledge for energy and comfort related trends and future directions. The main table summarizes 121 works closely related to the mentioned issue. Key areas focused on include comfort parameters, control systems, intelligent computational methods, simulation tools, occupants' behavior and preferences, building types, supply source considerations and countries research interest in this sector. Trends for future developments and existing research in this area have been broadly studied and depicted in a graphical layout. In addition, prospective future advancements and gaps have also been discussed comprehensively[48].

30. Haiyan Yan (2013) Thermal comfort and building energy consumption implications – A review

Buildings account for about 40% of the global energy consumption and contribute over 30% of the CO_2 emissions. A large proportion of this energy is used for thermal comfort in buildings. This paper reviews thermal comfort research work and discusses the implications for building energy efficiency. Predicted mean vote works well in air-conditioned spaces but not naturally ventilated buildings, whereas adaptive models tend to have a broader comfort temperature ranges. Higher indoor temperatures in summertime conditions would lead to less prevalence of cooling systems as well as less cooling requirements. Raising summer set point temperature has good energy saving potential, in that it can be applied to both new and existing buildings. Further research and development work conducive to a better understanding of thermal comfort and energy conservation in buildings have been identified and discussed. These include (i) social-economic and cultural studies in general and post-occupancy evaluation of the built environment and the corresponding energy use in particular, and (ii) consideration of future climate scenarios in the analysis of co- and tri-generation schemes for HVAC applications, fuel mix and the associated energy planning/distribution systems in response to the expected changes in heating and cooling requirements due to climate change[49].

31. D. Chemisana (11 Nov 2014) Evaluation of a multi-stage guided search approach for the calibration of building energy simulation models

This paper is focused on increasing the knowledge on methods for calibrating BES models and to get more insights of different approaches for the optimization of the calibration process. The paper will be centre in the evaluation of a multistage guided search approach. It defines an iterative optimization procedure, which starts with the assignment of probabilistic density functions to the unknown parameters, followed by a random sampling and running batch of simulations. It then finishes with an iterative uncertainty and sensitivity analysis combined with a re-assignment of the ranges of variation of the strong parameters. The procedure converges when no new influencing parameters are found. This method is applied to a real case study consisting of an unoccupied office building located in Lleida (Spain). The measured indoor temperature has been used to determine the uncertainty and precision of the method. The effect of the size of the sampling, the number of iterations and the parameters of the global sensitivity method are analyzed in detail. The results of this paper exemplify the degree of accuracy of multistage guided search approaches, and illustrate the reasons how these analyses can contribute to the improvement of more refined calibration methods[50].

32. Chirag Deb (2017) A review on time series forecasting techniques for building energy consumption

Research into methods of improving energy efficiency and preserving the environment benefits greatly from the capacity to predict a building's energy needs. Planning and energy optimisation of facilities and schools benefit greatly from reliable energy forecasting models. Energy analysis and scenario predictions for brand-new constructions often rely on computer simulation approaches because to the lack of accessible historical data. However, artificial intelligence and machine learning approaches have shown to be far more precise and quicker when applied to existing buildings using time series energy data. In this paper, we survey the state-of-the-art in machine learning approaches to energy consumption forecasting across time series. While this study focuses on a specific method of analysing time series data, it is not restricted to that method since energy information is regularly co-analyzed with various time series variables, such as weather and indoor ambient conditions. Nine of the most widely used forecasting methods based on machine learning are examined. Hybrid models, which use data from several sources to make a single prediction, are also discussed in detail. Series of times energy forecasting for buildings is best performed using different hybrid model combinations.

33. William Chung (17 Nov 2010) Review of building energy-use performance benchmarking methodologies

The purpose of this study is to provide an overview of the mathematics behind benchmarking system development, to explain the techniques' qualities, and to categorise two distinct types of benchmarking systems according to those features. While benchmarks systems are built utilising the energy-use characteristics of a large number of references construction sites, we discover that the results of benchmarking may be utilised to motivate low-performing reference buildings to become more energy-efficient. However, some authorities provide benchmarking data to the press since such systems also serve as a public gauge of buildings' energy-use efficiency. This is helpful because it puts the emphasis on the owners and developers of non-reference buildings that are underperforming. However, not all benchmarking systems are available to the general public (i.e., other non-reference building owners). We notice that there are two types of benchmarking system, public evaluating and internal benchmarking, depending on whether or not the final benchmarking system may be utilised in public. The processes used to create these two kinds of benchmarking systems are distinct.

34. Zhihong Pang (2018) Application of mobile positioning occupancy data for building energy simulation: An engineering case study

In order to accurately simulate a building's energy use, occupancy data must be provided as an input parameter. The use of real-time occupancy data for building energy simulation is hindered, however, because current methods for obtaining such data via the conventional occupancy detection technology necessitate either the implementation of a large-scale sensor network or complex and time-consuming computational algorithms. The vast amounts of people location data created by smartphone users and kept on cloud servers provide an opportunity to address this critical issue in the age of the mobile internet. One possible alternative to conventional occupancy detection techniques is the use of mobile data sources, since they may be carefully monitored, updated in real time, and accessed at an affordable time and labour cost upon client agreements in specific places. In this work, we look at the possibility of using mobile-internet positioning data to improve energy modelling in buildings and discuss some of the implications of doing so. The article begins with a brief overview of the strengths and weaknesses of the most well-known occupancy detection techniques. Next, the idea behind the mobile internet based occupancy detection technique is presented. In this work, we establish a framework for making use of this kind of occupancy data in energy simulations of buildings. As a proof of concept, the authors employ a complete building simulation programme called Energy Plus to mimic the energy performance of a complicated skyscraper in Shanghai. The information from the BAS and the mobile-internet-based occupancy statistics are used to calibrate the system. The simulation results demonstrate that occupancy data collected through mobile internet may enhance the forecast accuracy of the building model.

35. Luis Pe´ rez-Lombard (13 Oct 2008) A review of benchmarking, rating and labelling concepts within the framework of building energy certification schemes

The energy consumption of a building cannot be reliably simulated without occupancy data. The enactment of a large-scale network of sensors or complex and time-consuming computations are the current methods to acquire such data via the conventional room identification technology, limiting the use of real-time utilisation data for energy consumption simulation. A solution to this pressing problem of the cell phone era may be found in the mountains of location data generated by smartphones and stored on remote servers. The utilisation of mobile data sources is an alternative to more traditional methods of occupancy detection since they may be closely monitored, refreshed in real circumstances, and accessible at a reasonable time and manpower cost based on client arrangements in particular locations. In this paper, we explore the potential of leveraging mobile-internet location data to enhance energy forecasting in building and talk about some of the consequences of doing so. At the outset, the paper provides a high-level analysis of the benefits and drawbacks of the most popular occupancy detection methods. The concept of the occupancy detection method using mobile internet is then introduced. In this study, we develop a system to incorporate such occupancy information into energy modelling for buildings. The authors use a full building simulation tool called Energy Plus to simulate the energy efficiency of a complex Shanghai skyscraper as a proof the concept. The system is adjusted depending on data collected from the BAS together with mobile internet-based occupancy statistics. The simulation results illustrate how occupant data gathered through mobile internet access may improve the building model's prediction accuracy.

36. Babak Raji (7 Feb 2015) the impact of greening systems on building energy performance: A literature review

Designers and regulators are motivated to seek out energy efficient techniques for sustainable development by the scarcity of the assets and environmental challenges created by human activity. The construction industry is responsible for a significant portion of the planet's energy use and CO2 emissions. There is hope in the form of green infrastructure solutions for improving the energy efficiency of buildings. Nonetheless, a greenery system may provide several advantages to a structure, including but not limited to energy savings. Roof greening, horizontal ecological restoration, rooftop growing, and sky gardens (interior and outdoor) are some of the most typical locations for plants in buildings, particularly in the planning of tall structures. As a result, this paper's primary objective is to conduct a literature assessment of all available greening technologies in terms of the energy effect they have. The impact of houseplants on both thermal comfort and IAQ will be examined. Additionally, a summary of how various eco-systems of vegetation fare in various climates is provided.

37. Alessandro Maccarini (7 July 2021) Detailed cross comparison of building energy simulation tools results using a reference office building as a case study

Through pre-design, commissioning, and operation, building systems may be optimised with the use of Building Energy Simulation (BES) technologies. The usage of BES tools in academia and business is on the rise. There is a constant stream of releases of both new and modified BES utilities. Each tool has its own validation procedure, and it is unusual for many tools to be compared using the same case study. This paper compares the monthly and hourly results of the same characteristic office cell modelled by each of the widely used dynamic simulation tools (i.e. energy use Plus, TRNSYS, Simulink educational institutions CarnotUIBK and ALMABuild, IDA ICE, Modelica/Dymola, and DALEC) and PHPP (a well-known quasi-steady-state tool). The cell was defined within the IEA SHC Task 56. The quality of the simulation results is heavily influenced by the parametrization process since various tools demand varying degrees of input information, which sometimes do not match with available data. In this work, we cross-compare various tools and analyse commonly used statistical indices and normalisation procedures to determine how much of a difference there really is. Results that reflect an acceptable amount of difference between the predictions of a single model versus the expected results of all models are identified by using the deviation levels provided by ASHRAE Guideline 14-2014. The modellers had to go through a number of cycles until they found a solution that worked well with all of the tools. Defining the characteristics of architectural components and providing future cross-modal comparative resources This paper provides a concise overview of the procedures that were carried out. An explanation of the modelling methodologies offered by all the tools for this particular scenario example is also included, along with a comparison of the tools' findings, to aid users in making an informed decision about which simulation tool is most suited to their needs.

38. Ricardo M.S.F. Almeida (19 April 2015) towards a methodology to include building energy simulation uncertainty in the Life Cycle Cost analysis of rehabilitation alternatives

LCC analysis should be used to determine the most cost-effective option for building restoration. The portion of those expenses attributable to energy use is particularly difficult to predict with precision. In order to quantify and include this uncertainty in LCC estimates, a unified technique is proposed here. The technique uses Monte Carlo modelling to derive probability distributions of energy use. When added to an LCC analysis, these costs provide decision-makers a quantitative indication of the economic impact uncertainty associated with various restoration options. The paper explains the approach and shows how it was used in a specific scenario. The primary goal of these findings is to serve as examples of how the approach may be used and to highlight crucial elements such pre-processing of input data, convergence analysis, and appropriate economic measurements. As trustworthy stochastic information provided are not readily accessible, the approach is not yet prepared for a generalized application. Nevertheless, the findings of this study demonstrated how this strategy may impact judgements if the durable nature of each option was understood.

39. Neda Yaghoobian (2012) an indoor–outdoor building energy simulator to study urban modification effects on building energy use Model description and validation

Although there have been great strides in modelling the energy consumption of individual building with urban awnings, more complex and efficient models are required to fully comprehend the heat-based connection among buildings and their environments. In particular, understanding how the composition of buildings, the geometry of canyons, meteorological conditions, and all of them affect heat transmission in urban areas is important for assessing policy solutions. The Urban Ambient Temp TUF-IOBES is a buildings-to-canopy model that estimates cooling/heating demands and energy usage in buildings by simulating internal and outdoor building thermal conditions and heat fluxes in an urban region. Taking into consideration real-world weather conditions, interior temperature sources, building and municipal material qualities, building envelope (envelope's) composition (windows, insulation, HVAC equipment), and so on, the indoor and outside energy balancing processes are dynamically integrated. TUF-IOBES can also model the impact of AC byproduct heat on the temperature of the air above a city's canopy. Multi-model comparisons are made for yearly and daily heating and cooling loads, and TUF-IOBES's transient heat conduction is confirmed against an analytical solution. Concrete and asphalt pavements' effects on building energy consumption are analysed using TUF-IOBES.

- **Building energy consumption & energy-efficient building envelope by using software**

40. Pranal Prakash JADHAV 4 [November] Assessment of Building Energy by Performing Simulation with BIM

The primary element influencing Building Lifecycle Cost and another external environment component is Building Energy Performance. The necessity to identify a building's current energy situation and manage it properly is growing. The building's present energy usage pattern must be analyzed correctly if it is to be managed efficiently. The purpose of this research is to use Building Information Modelling (BIM) to conduct Building Energy analysis relative to various factors. The adaptability of Building Information Modelling (BIM) in many sub disciplines of Civil Engineering is becoming more apparent. BIM allows for the analysis to be performed with the right instruments, yielding accurate findings. Using modelling software, a detailed model of the building is created, which is then analyzed using other software programmes. The information gleaned from these analyses is then used to develop a plan for maximising the building's efficiency in terms of its usage of energy. The goal is to reduce building energy costs while increasing sustainability via the implementation of suggested building modifications and changes in user behaviour.

41. Duygu Utkucu (2020) Interoperability and data exchange within BIM platform to evaluate building energy performance and indoor comfort.

When planning a building's layout, it's important to think about things like thermal comfort and air quality. This calls for a deep dive into the design process, requiring collaboration across disciplines, and a plethora of analytical methodologies and simulation tools. Data collisions and losses are two potential downsides of this action that should be avoided if possible. One possible solution is to use a 3D model of the building that takes into account not just its thermal capacity and climatic dynamics, but also its functional and physical requirements. Building information modelling (BIM) may serve as a foundation for such an endeavour. Given the complexity of various analytic methodologies, it is important to identify and ensure that all used programmes are compatible with one another. This research intends to enhance the building design procedure by formulating a strategy for identifying the degree to which the employed programmes for assessing the energy efficiency and interior comfort of a building using the BIM approach are compatible with one another. To ensure the viability of the suggested technique and to determine the interoperability boundaries during data transmission, a case study is performed. This is why we construct and assess three primary models of analysis. The 3D building model is used to develop the building's architecture in accordance with the building's physical conditions; the CFD of natural ventilation is used to develop the indoor comfort conditions in accordance with the building's temperature, humidity, and air velocity; and the building energy model is used to develop the building's energy performance in accordance with the building's architecture and its systems. Then, a BIM system is used to bring everything together. Therefore, the suggested BIM-based technique makes software integration more simpler.

42. Ashaprava Mohanta (2021) Building envelope trade-off method integrated with BIM-based framework for energy-efficient building envelope

Recent years have seen a dramatic rise in interest in green and energy-efficient construction in India. However, there are a few obstacles to this uptick, such as a lack of certified energy-efficient buildings and a centralised collection of green materials. Using the Building Envelope Trade-off Method (BETM) in the preliminary stages of building design, this research proposes a Building Information Modelling (BIM)-based workflow that accommodates the current trend of energy-conscious building envelopes. With its simplified calculations based on thermal characteristics, orientation, and surface area, BETM paves the way for an energy-efficient envelope. Common building components and materials are modelled into a BIM library. Aiming to assess the efficacy of the created methodology, 216 envelope mixtures involving alternate exterior substances, positions, and passive facade elements are simulated and compared. Results reveal that for the investigated orientations, the envelope performance coefficient ratio is identical, but the peak conditioning total load (PCTL) is reduced by 0.35 percent and 12.49 percent, respectively, compared to the original as-built case. The PCTL is useful for doing energy analyses of buildings while taking contextual factors into account. The improved performance of the building envelope required by the Renewable Energies Building Code is guaranteed by the established process.

43. Nariman Mostafavi (2013) Envelope retrofit analysis-using eQUEST, IESVE Revit Plug-in and Green Building Studio: a university dormitory case study

Using DOE-2 eQUEST, the IESVE Revit Plug-in, and Autocad Green Building Studio, we estimate the potential energy savings from a planned envelope renovation on a university dorm. By removing and replacing all original openings and externally non-structural infill the material panels and by installing more insulating materials between the recently installed brick panels and the hinterland brick and mortar unit walls, the study will examine the chance of energy savings created. Four seven-story dorms, totaling about 7,000 square metres, built in the 1960s will undergo renovations. To evaluate the efficacy of the three modelling tools, we compare the results of baseline design simulations with actual energy consumption data. To evaluate the effectiveness of the proposed retrofit, we compared the outcomes of each retrofitted design option to the baseline and calculated the percentage decrease in CO2 emissions. Each modelling program's benefits and drawbacks are also explored.

44. D. Connolly (2009) a review of computer tools for analyzing the integration of renewable energy into various energy systems

This paper includes a review of the different computer instruments for assessing the feasibility of renewable energy integration. After initially considering 68 tools, the study was narrowed down to 37 in consultation with the tool's creators or suggested points of contact. Based on the findings of this research, an appropriate energy instrument for analysing the integration of green electricity into diverse energy-systems may be selected. A report demonstrates that the 'optimal' energy tool is very context-dependent, and therefore, there is no one energy tool that solves all problems associated with renewable energy integration. The perception of the 'ideal' energy tool will change depending on a number of factors, including the energy-sectors looked at, innovations accounted for, the time scale used, tool the availability, and previous studies, as well as typical uses for the 37 tools studied (from analysing single-building applications to national energy systems). In conclusion, the data presented here should be sufficient to point a decision-maker in the direction of an appropriate energy instrument for the study at hand.

45. Kendrick T. Aung (2011) Simulation tools for renewable energy projects

Both industrialised and developing nations have increasingly relied on renewable energy sources in recent years. There have been significant textbook updates on the topic of renewable and alternative energy sources. Courses in renewable and alternative energy are also being made available to undergraduate and graduate students at several institutions. Classes like these might benefit from the usage of energy resource simulation and analysis tools. This research uses data collected from a Lamar University optional course to compare and contrast some of these simulation tools and assess their usefulness. Students are expected to execute a design project throughout the course that focuses on sustainable energy technologies like solar, wind, or geothermal heating and cooling. In this study, we take a look at a number of different modelling tools, including NREL's Solar Advisor Model (SAM), NRC's Rescreen, and Vela Solaris' PolySun. Using these programmes, many example projects were modelled and simulated for various renewable energy sources, including photovoltaic, wind, solar water heating, and geothermal systems. Modelling, product databases, validation, and economic analysis were only some of the criteria used in comparing and assessing these resources. Each programme has powerful modelling and simulation features that may be used in the classroom.

46. Ehsan Kamel (2019) Review of BIM's application in energy simulation: Tools, issues, and solutions

BIM was developed at first to facilitate communication across the several software programmes used in the building industry, including those for architectural design, structural design, mechanical design, and electrical design. Energy simulation joins the ranks of uses that previously included 3D model creation, structural analysis, cost prediction, and mechanical analysis. Different forms of building data are stored in BIM files created by a wide range of CAD programmes functioning as BIM authoring tools. In addition, many BIM files may be imported into a number of BEM systems for use in energy simulation. In order to help design experts at different stages of a project and for different reasons choose the most appropriate tool, it is necessary to examine and categorise these tools and their varying capabilities and limits. In addition, it's important to comprehend the problems associated with BIM and BEM tools' lack of interoperability and data interchange so that appropriate remedial middleware technologies may be developed. By presenting a thorough categorization for these issues and evaluating the potential remedies, this article evaluates the difficulties, problems, and weaknesses of the BIM-to-BEM interoperability process (BBIP). In addition, the study details how a corrective middleware, written in Python by the authors, may be used to alter a gbXML file before it is used in energy simulation, thereby fixing the problems associated with the building envelope in BBIP. In order to accomplish this, a literature review on research projects centred on various BIM schemas (including IFC and gbXML) and energy simulation tools (including Green Building Studio (GBS), Design Builder, Integrated Environmental Solutions (IES), and Open Studio) that can read these files is presented. Challenges in using BIM for energy simulation are also discussed, including interoperability problems, a lack of standards, and a dearth of simple approaches to expanding current BIM schemas and the accompanying solutions. Keeping the building envelope in mind, we examine three case studies to highlight the difficulties and complexities associated with BBIP in Revit, GBS, and Open Studio. Case studies like this may also be used to examine the implementation of remedial middleware tools like those created in the provided research.

47. Tom Lloyd Garwood (2018) a review of energy simulation tools for the manufacturing sector

The manufacturing industry is highly competitive on a worldwide scale, and the public is more aware of the need of taking action to slow climate change. The current trend in manufacturing is to decrease expenses and improve environmental impact without lowering product quality or quantity. Production facilities that make efficient use of energy might benefit from reduced operating expenses. Companies may make informed retrofit choices based on energy usage and other parameters, such as resource consumption, throughput, and overhead expenses, with the use of simulations. While both Building Energy Modelling (BEM) and Manufacturing Process Simulation (MPS) have seen considerable usage in the past, they have mostly remained autonomous from one another, limiting the scope of the simulation window that may be used to spot opportunities for energy savings. This article discusses the attempts to integrate BEM and MPS, or parts of both, into a unified methodology, and describes the modelling methodologies and simulation tools that have been utilised or are now available. Manufacturing facility layers including manufacturing equipment, process lines, and Technical Building Services (TBS) might be simulated using this method. This broadened the lens through which energy efficiency improvements might be identified across a wide range of operations and many different sectors of the industrial economy. In doing so, we identify research gaps that might be exploited in future studies, and we emphasise the difficulties of adding BEM into production simulation. Needs for a comprehensive energy simulation tool tailored to the needs of a manufacturing plant were outlined, as were methods for quickly generating 3D building geometry from site data or existing BIM, all in a suitable format for energy simulations of existing factory buildings.

- **Building modeling design and analysis**

48. Salman Azhar (2011) Building information modeling for sustainable design and LEED® rating analysis

The need for eco-friendly structures is greater than ever now. The design and preconstruction phases of a building are when the bulk of choices pertaining to its sustainable characteristics are made. In the United States, LEED® (Leadership in Energy and Environmental Design) is the standard for green building certification. Designers working on LEED certified buildings must do in-depth sustainability evaluations of the building's shape, materials, context, and MEP systems. By combining data from many fields into a single model, Building Information Modelling (BIM) improves upon previous approaches of doing these kinds of analysis. To highlight the value of BIM in sustainable design and the LEED certification procedure, a case study was undertaken on the Perdue School of Business building at Salisbury University. To begin, a conceptual framework was created to define the connection between Building Information Modelling (BIM) and LEED® certification. The next step was to use this case study to verify the framework. The findings of this research suggest that BIM-based sustainability analysis software may be used to directly or indirectly create paperwork supporting LEED credits. This technology has the potential to significantly reduce the time and resources needed for LEED certification, compared to more conventional approaches.

49. Shem C. Heiple (2007) Using Building Energy Simulation and Geospatial Modeling Techniques in Determine High Resolution Building Sector Energy Consumption Profiles

Using geographical scales as fine as the taxlot or parcel, an approach is described for predicting hourly and monthly consumption of energy patterns in the construction industry. In a Geographical Information System (GIS) context, the technique integrates yearly building energy calculations for city-specific prototype structures with publicly accessible geographical data. For any given day, a raster output of hourly data may be retrieved and exported down to the level of a single parcel (100m). The approach may be used to estimate household and business electricity and natural gas usage on a day-to-day basis in nearly any major city in the United States. The generated profiles may be used to calculate the amount of anthropogenic waste heat, both sensible and latent, that is produced by a given building's energy usage. This method is intended for use in atmospheric modelling on a city-wide scale to further inform heat islands in cities and air quality research. The incorporation of waste heat data with high temporal and geographic precision is a major step forward in such uses.

50. Shady Attia (2012) Simulation-based decision support tool for early stages of zero-energy building design

Architectural practise would benefit from decision support systems that include modelling energy usage into the early stages of zero energy buildings. There have been many advances in simulation software over the last decade, but no really useful programmes have emerged to address the unique needs of people living in warm climes. More importantly, the problem of informing the design prior to the decision-making stage is mainly ignored by the bulk of current tools, which instead prioritise analysing the design choices after the decision has been made. This study introduces an energy-focused software tool that is tailored to the Egyptian environment and offers decision-makers useful information in an effort to help them achieve zero-energy status. By combining sensitivity analysis modelling with renewable energy modelling software (Energy Plus), a home benchmark was created to serve as a decision support tool for architects and engineers as they evaluate the thermal comfort and thermal efficiency of preliminary design options. The findings of a case study and usability testing are given to demonstrate the tool's efficacy in validating hypotheses and informing decisions.

51. Christoph Reinhart (2006) findings from a survey on the current use of daylight simulations in building design

In this article, we provide the results of an online poll on the state of daylight simulations in architectural practise today. The poll was taken between December 2nd, 2003 and January 19th, 2004. The poll was completed by 185 people from 27 different countries. Canadians, Americans, and Germans made up the bulk of the responders, each accounting for 20%. The majority of people took part in the study through email list for the simulation of construction. They identified themselves as being involved in fields such as energy consulting (38%) and engineering (38%), architecture (31%), lighting design (31%), and research (23%). They mostly focused on commercial buildings like schools and workplaces. Overwhelmingly, 91% of people said that daylighting was a consideration in their building's design. Those who didn't think about daylighting cited a lack of knowledge and a reluctance on the part of their customers to pay more for the convenience. Seventy-nine percent of those who were thinking about daylighting employed some kind of digital model. Many participants were recruited by creating simulation email groups, which explains why the sample is so heavily skewed towards computer simulations. Complexity of tools and lack of documentation were cited as problems by participants. The majority of users of daylight simulators trained themselves. Design development saw a dramatic increase in tool utilisation compared to schematic design. The vast majority of survey takers supplied clientele with the outcomes of parameter analyses conducted using daylighting software. The most frequent results of daylighting simulations were daylight factor and interior illuminances, whereas the most common design factors affected by daylighting analyses were shading type and control. While confidence in the accuracy of daylighting instruments has increased, the utilisation of scale model measurements has sharply declined since a 1994 study was conducted. In a survey of professionals in the field of daylight simulation, 42 distinct programmes were identified as being used often; nevertheless, more than half of the programme choices were for tools that utilise the RADIANCE simulation engine, demonstrating the program's preeminence within the field.

52. Yekang Ko (2013) Urban Form and Residential Energy Use: A Review of Design Principles and Research Findings

Many studies have looked at how city layout affects household energy use, but it can sometimes be difficult to make sense of the results due to differences in study size and methodology. This article provides an analysis of research on the effects of urban design on household energy consumption, with a focus on the heating and cooling sectors of the industry. Accommodation type, density (physical tightness and concentrating unit density), society layout (street position as well as configuration), and planting along with surface area are all discussed in relation to research on how they affect residential energy use in this article. Three types of studies—experiments, simulation models, and statistical analyses of empirical data—summarize the literature on each of these elements. Future research implications and planning recommendations are then presented.

53. Peter Tozzi Jr. (2017) a Comparative Analysis of Renewable Energy Simulation Tools: Performance Simulation Model vs. System Optimization

No matter where you are in your education or experience with renewable energy, there is software out there that can help you model and optimise your system. Optimisation models may assist design optimal system sizes to fulfil energy objectives including minimising life-cycle operating expenses or maximising carbon reduction, while models for performance simulate electricity outcomes with user-specified system configurations. In this study, we break down the models we've looked at into three distinct levels of project scope: multi-scale RE tools, district-level tools, and regional-level tools. Each category's tools will be examined compared in comparison to another to highlight their shared features and distinct distinctions. Finally, this study will summarise which methods work best on which scales.

54. Shady Attia (2011) State of the Art of Existing Early Design Simulation Tools for Net Zero Energy Buildings: A Comparison of Ten Tools

The use of Building Performance Simulation (BPS) technologies in the early design stages of Net Zero Energy Buildings (NZEBs) has proved crucial due to the difficulties inherent in designing such structures. When used in the beginning of the design process, BPS approaches may be helpful in this setting. During this critical stage, when the building proportions and surface are being addressed, architects are hindered by the shortcomings of BPS tools. This research examines eleven early design BPS tools in order to highlight such limitations and is part of the Intergovernmental Energy Agency's (IEA) Task 40: Achieving Net Zero Energy Buildings. The goal is to specify how architects may make best use of and integrate these technologies into the structure of NZEBs. HEED, e-Quest, ENERGY-10, Vasari, Solar Shoebox, Open Studio Plug-in, IES-VE-Ware, Design Builder, ECOTECT, and BEopt are just some of the products that have been put through their paces. Usability, optimisation, compatibility, preciseness, and integration into the design process are the five criteria used to evaluate the tools. The findings detail the constraints of available tools and the essential necessities for achieving the NZEB's intended outcomes.

55. Adrian Chong (21 Jan 2021) eplusr: A framework for integrating building energy simulation and data-driven analytics

The use of building energy simulation (BES) has become commonplace in the study of environmental and energy performance of buildings under various design and retrofit scenarios. BES findings need data-driven analytics for proper interpretation and analysis in order to show patterns and deliver actionable insights. However, there is currently no way to seamlessly integrate BES with data-driven analytics. In this article, we introduce eplusr, a R package for using Energy Plus for data-driven analytics. The R package is available through the universal CRAN (Comprehensive R Archive Network) distribution system. The suggested framework is built on a data-centric design approach and prioritizes tighter coordination between BES and data-driven analytics. It offers a well-defined format for inputs and outputs that may be seamlessly integrated into preexisting data analytics processes. To aid with repeatability studies, the R package also offers a framework for bringing a portable and adaptable computation infrastructure for building energy modelling.

5. CONCLUSION

Finally, we can confirm that the entire running cost of the building's energy systems rises. The impact of new structures around the building.

Assumed in the research increases power use, but the impact may be more pronounced in a different setting (one with harsher weather, for instance), with a different orientation for the structure, or with a higher proportion of opaque Interfaces or transparent Interfaces (e.g., a medium or large ratio).

Increases in energy usage in another location (with more severe implications) are taken into account in the research. Climate-related factors include, but are not limited to, the use of different building orientations and layouts, a higher ratio of opaque to clear surfaces, or obscure covers (e.g., medium or bigger ratio), the effect may be greater.

The study takes into account an increase in the use of electricity at a different location (for instance, due to the fact that severe weather has been reinforced), with various building directions, or by using more opaque materials. I'd also want to draw attention to some of the special factors that are at play in this situation:

- The structure isn't very well; there is really no appropriate facade exposition capable of maximizing solar benefits;
- The structure is situated in a location with warm summers, which necessitates a larger demand for proper shade.to minimize unfavorable overheating and a significant requirement on ventilation systems in the summer.

In this situation, the shade given by additional buildings with in future scenario contributes positively. Furthermore, in old structures that have not been repaired and vigorously modernized, the

No air conditioning is available. The ratio of the building's transparent/opaque surfaces to the whole constructed environment is around 30%, which is fairly low compared to the conventional and current design and ensures minimum air conditioning is required during the summer. Additionally, the increased thermal inertia of the building's façade aids in its stability. Indoor Temperatures in the Summer However, the absence of insulation makes the effect worse.

winter There is no good orientation of the building's facade to take advantage of solar heat gain.

The need for adequate shading to avoid overheating is heightened, and ventilation or cooling is of more importance in the summer, since the building is located in a region with mild summers. Both the already-existing buildings and any prospective ones that may provide shading help this situation immensely. In addition, a cooling system is often absent in older buildings that have not undergone maintenance and energy modernization.

The ratio of transparent to opaque surfaces in the building is around 30%, which is fairly low compared to the national or current average and ensures little air-conditioning needs during the warmer months. Additionally, the increased heat inertia of the building's exterior aids in maintaining consistent interior temperatures throughout the summer. The absence of insulation, on the other hand, has a far more severe effect when it's cold.

Greenhouse gas emission and primary consumption of energy reduction strategies that don't include evaluating and retrofitting a structure are incomplete. Due to the scarcity of readily available off-the-shelf technology or methods to gather satellite data of diverse modalities in buildings, we developed a novel modular and extensible sensor network in evaluating building performance. As other technologies improve, such as cheaper batteries and electrical components like sensors, we expect the cost of measurement-based building assessment to decrease as well.

By making just a few small adjustments to the building's construction, the current structure was transformed into a much more energy-efficient structure. An energy-efficient structure is one that uses less energy overall. This results in a marginal decrease in the release of greenhouse gases. As can be seen from the data, proper pre-construction planning of a project has the potential to significantly alter the building industry.

6. REFERENCES

[1] Seetharaman, K. Moorthy, N. Patwa, Saravanan, and Y. Gupta, “Breaking barriers in deployment of renewable energy,” *Heliyon*, vol. 5, no. 1, p. e01166, 2019, doi: https://doi.org/10.1016/j.heliyon.2019.e01166.

[2] M. A. Musarat, W. S. Alaloul, and M. S. Liew, “Impact of inflation rate on construction projects budget: A review,” *Ain Shams Eng. J.*, vol. 12, no. 1, pp. 407–414, 2021, doi: https://doi.org/10.1016/j.asej.2020.04.009.

[3] Y. K. Dwivedi *et al.*, “Opinion Paper: ‘So what if wrote it?’ Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy,” *Int. J. Inf. Manage.*, vol. 71, p. 102642, 2023, doi: https://doi.org/10.1016/j.ijinfomgt.2023.102642.

[4] S. O. Abioye *et al.*, “Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges,” *J. Build. Eng.*, vol. 44, p. 103299, 2021, doi: https://doi.org/10.1016/j.jobe.2021.103299.

[5] F. S. Hafez *et al.*, “Energy Efficiency in Sustainable Buildings: A Systematic Review with Taxonomy, Challenges, Motivations, Methodological Aspects, Recommendations, and Pathways for Future Research,” *Energy Strateg. Rev.*, vol. 45, p. 101013, 2023, doi: https://doi.org/10.1016/j.esr.2022.101013.

[6] M. Santamouris and K. Vasilakopoulou, “Present and future energy consumption of buildings: Challenges and opportunities towards decarbonisation,” *e-Prime - Adv. Electr. Eng. Electron. Energy*, vol. 1, p. 100002, 2021, doi: https://doi.org/10.1016/j.prime.2021.100002.

[7] A. Hajare and E. Elwakil, “Integration of life cycle cost analysis and energy simulation for building energy-efficient strategies assessment,” *Sustain. Cities Soc.*, vol. 61, p. 102293, 2020, doi: https://doi.org/10.1016/j.scs.2020.102293.

[8] J. Kneifel and D. Webb, “Life cycle cost manual for the federal energy management program,” *NIST Handb. 135*, pp. 1–295, 2020, [Online]. Available: https://nvlpubs.nist.gov/nistpubs/hb/2020/NIST.HB.135-2020.pdf

[9] R. K. E.-D. El-Mallah, A. A. el H. Aref, and S. Sherif, “The role of social responsibility in protecting the environment – a case of the petrochemical companies in Alexandria Governorate,” *Rev. Econ. Polit. Sci.*, 2019, doi: 10.1108/reps-04-2019-0052.

[10] A. Terry A. Jacobs, “Sustainability: Where Is LEED Leading Us?” 2020. [Online]. Available: https://ispe.org/pharmaceutical-engineering/march-april-2020/sustainability-where-leed-leading-us

[11] Sieglinde Fuller, “Life-Cycle Cost Analysis (LCCA).” 2016. [Online]. Available: https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca

[12] H. Islam, M. Jollands, S. Setunge, and M. Bhuiyan, “Optimization approach of balancing life cycle cost and environmental impacts on residential building design,” *Energy Build.*, vol. 87, pp. 282–292, Jan. 2015, doi: 10.1016/j.enbuild.2014.11.048.

[13] J. Morrissey and R. Horne, “Life cycle cost implications of energy efficiency measures in new residential buildings,” *Lancet*, vol. 43, pp. 915–924, Apr. 2011, doi: 10.1016/j.enbuild.2010.12.013.

[14] R. Kansal and G. Kadambari, “Green Buildings: An Assessment of Life Cycle Cost,” vol. 8, Feb. 2011.

[15] M. González-Torres, L. Pérez-Lombard, J. F. Coronel, I. R. Maestre, and D. Yan, “A review on buildings energy information: Trends, end-uses, fuels and drivers,” *Energy*

Reports, vol. 8, pp. 626–637, 2022, doi: https://doi.org/10.1016/j.egyr.2021.11.280.

[16] E. Eia-eiadoegov and G. Mcgrath, "U.S. Department of Energy Energy Information Administration Form EIA-860 (2006) PURPOSE," vol. 860, no. 202, pp. 1–19, 2006.

[17] H. Omrany, "Optimization of Building Energy Performance through Passive Design Strategies Optimization of Building Energy Performance through Passive Design Strategies," no. December 2015, 2016, doi: 10.9734/BJAST/2016/23116.

[18] C. Ionescu, T. Baracu, G.-E. Vlad, H. Necula, and A. Badea, "The historical evolution of the energy efficient buildings," *Renew. Sustain. Energy Rev.*, vol. 49, Sep. 2015, doi: 10.1016/j.rser.2015.04.062.

[19] R. K. Jaysawal, S. Chakraborty, D. Elangovan, and S. Padmanaban, "Concept of net zero energy buildings (NZEB) - A literature review," *Clean. Eng. Technol.*, vol. 11, p. 100582, 2022, doi: https://doi.org/10.1016/j.clet.2022.100582.

[20] H. R. S. Jewel Rana Rakibul Hasan and V. W. Y. Tam, "Impact assessment of window to wall ratio on energy consumption of an office building of subtropical monsoon climatic country Bangladesh," *Int. J. Constr. Manag.*, vol. 22, no. 13, pp. 2528–2553, 2022, doi: 10.1080/15623599.2020.1808561.

[21] A. Hajare and M. Kadam, "Life Cycle Cost Analysis of Mass Housing Project: A Comparative Study of Two Cases," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 11, no. 6, pp. 1–5, 2020, doi: 10.22214/ijraset.2023.53472.

[22] L. Saini, C. Meena, B. P Raj, N. Agarwal, and A. Kumar, "Net Zero Energy Consumption Building in India: An Overview and Initiative towards Sustainable Future," *Int. J. Green Energy*, Jul. 2021, doi: 10.1080/15435075.2021.1948417.

[23] G. Singh and R. Das, "Comparative assessment of different air-conditioning systems for nearly/net zero-energy buildings," *Int. J. Energy Res.*, vol. 44, Jan. 2020, doi: 10.1002/er.5065.

[24] A. Baig, F. Kimiaghalam, R. Kumar, J. Ma, and A. Fung, "Natural gas engine driven heat pump system – a case study of an office building," *Int. J. Green Energy*, vol. 17, pp. 1–12, May 2020, doi: 10.1080/15435075.2020.1763355.

[25] D. Coakley, P. Raftery, and M. Keane, "A review of methods to match building energy simulation models to measured data," *Renew. Sustain. Energy Rev.*, vol. 37, pp. 123–141, Sep. 2014, doi: 10.1016/j.rser.2014.05.007.

[26] D. B. Crawley *et al.*, "EnergyPlus: creating a new-generation building energy simulation program," *Energy Build.*, vol. 33, no. 4, pp. 319–331, 2001, doi: https://doi.org/10.1016/S0378-7788(00)00114-6.

[27] V. s. K. V. Harish and A. Kumar, "A review on modeling and simulation of building energy systems," *Renew. Sustain. Energy Rev.*, vol. 56, pp. 1272–1292, Apr. 2016, doi: 10.1016/j.rser.2015.12.040.

[28] C. Bussar *et al.*, "Large-scale Integration of Renewable Energies and Impact on Storage Demand in a European Renewable Power System of 2050," *Energy Procedia*, vol. 73, pp. 145–153, 2015, doi: https://doi.org/10.1016/j.egypro.2015.07.662.

[29] K. J. Lomas, H. Eppel, C. J. Martin, and D. P. Bloomfield, "Empirical validation of building energy simulation programs," *Energy Build.*, vol. 26, no. 3, pp. 253–275, 1997, doi: https://doi.org/10.1016/S0378-7788(97)00007-8.

[30] M. Witte, R. Henninger, J. Glazer, and D. Crawley, *Testing and Validation of a New Building Energy Simulation Program*. 2001.

[31] Z. Tian, X. Zhang, X. Jin, X. Zhou, B. Si, and X. Shi, "Towards adoption of building energy simulation and optimization for passive building design: A survey and a review," *Energy Build.*, vol. 158, pp. 1306–1316, 2018, doi: https://doi.org/10.1016/j.enbuild.2017.11.022.

[32] M. Wetter, "BuildOpt - A new building energy simulation program that is built on smooth models," *Build. Environ. - BLDG Env.*, vol. 40, pp. 1085–1092, Aug. 2005, doi: 10.1016/j.buildenv.2004.10.003.

[33] M. Mourshed, D. Kelliher, and M. Keane, "Integrating building energy simulation in the design process," *IBPSA News*, vol. 13, pp. 21–26, Aug. 2003.

[34] L. Peeters, R. de Dear, J. Hensen, and W. D'haeseleer, "Thermal comfort in residential buildings: Comfort values and scales for building energy simulation," *Appl. Energy*, vol. 86, no. 5, pp. 772–780, 2008, doi: https://doi.org/10.1016/j.apenergy.2008.07.011.

[35] J. R. Simpson and E. G. McPherson, "Simulation of tree shade impacts on residential energy use for space conditioning in Sacramento," *Atmos. Environ.*, vol. 32, no. 1, pp. 69–74, 1997, doi: https://doi.org/10.1016/S1352-2310(97)00181-7.

[36] J. Venkatesh, B. Aksanli, J.-C. Junqua, P. Morin, and T. Rosing, *HomeSim: Comprehensive, smart, residential electrical energy simulation and scheduling*. 2013. doi: 10.1109/IGCC.2013.6604479.

[37] E. Aydin and D. Brounen, *The Impact of Policy on Residential Energy Consumption*. 2017. doi: 10.13140/RG.2.2.22971.52008.

[38] E. Frederiks, K. Stenner, and E. Hobman, "The Socio-Demographic and Psychological Predictors of Residential Energy Consumption: A Comprehensive Review," *Energies*, vol. 8, pp. 573–609, Jan. 2015, doi: 10.3390/en8010573.

[39] N. Kaza, "Understanding the spectrum of residential energy consumption: A quantile regression approach," *Energy Policy*, vol. 38, no. 11, pp. 6574–6585, 2010, doi: https://doi.org/10.1016/j.enpol.2010.06.028.

[40] M. Deru and P. J. Burns, "Infiltration and Natural Ventilation Model for Whole-Building Energy Simulation of Residential Buildings: Preprint," *ASHRAE Trans.*, vol. 109, Jan. 2003.

[41] A. S. An-Naggar, M. A. Ibrahim, and E. E. Khalil, "Energy Performance Simulation in Residential Buildings," *Procedia Eng.*, vol. 205, pp. 4187–4194, 2017, doi: https://doi.org/10.1016/j.proeng.2017.10.177.

[42] Y. Schwartz and R. Raslan, "Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study," *Energy Build.*, vol. 62, pp. 350–359, 2013, doi: https://doi.org/10.1016/j.enbuild.2013.03.022.

[43] T. Maile, M. Fischer, and V. Bazjanac, "Building Energy Performance Simulation Tools - a Life-Cycle and Interoperable Perspective," *Facil. Eng. Work. Pap.*, vol. 107, Jan. 2007.

[44] M. Saffari, A. de Gracia, S. Ushak, and L. F. Cabeza, "Passive cooling of buildings with phase change materials using whole-building energy simulation tools: A review," *Renew. Sustain. Energy Rev.*, vol. 80, pp. 1239–1255, 2017, doi: https://doi.org/10.1016/j.rser.2017.05.139.

[45] Y. Cho, S. Alaskar, and T. Bode, *BIM-Integrated Sustainable Material and Renewable Energy Simulation*. 2010. doi: 10.1061/41109(373)29.

[46] H. Li, Y. Yang, K. Lv, J. Liu, and L. Yang, "Compare several methods of select typical meteorological year for building energy simulation in China," *Energy*, vol. 209, p. 118465, 2020, doi: https://doi.org/10.1016/j.energy.2020.118465.

[47] Z. Wang and R. Srinivasan, "A review of artificial intelligence based building energy use prediction: Contrasting the capabilities of single and ensemble prediction models," *Renew. Sustain. Energy Rev.*, vol. 75, Nov. 2016, doi: 10.1016/j.rser.2016.10.079.

[48] P. Shaikh, N. Nor, P. Nallagownden, I. Elamvazuthi, and T. Ibrahim, "A review on optimized control systems for building energy and comfort management of smart sustainable buildings," *Renew. Sustain. Energy Rev.*, vol. 34, pp. 409–429, Jun. 2014, doi: 10.1016/j.rser.2014.03.027.

[49] L. Yang, H. Yan, and J. C. Lam, "Thermal comfort and building energy consumption implications – A review," *Appl. Energy*, vol. 115, pp. 164–173, 2014, doi: https://doi.org/10.1016/j.apenergy.2013.10.062.

[50] J. Cipriano, G. Mor, D. Chemisana, D. Perez, G. Gamboa, and X. Cipriano, "Evaluation of a multi-stage guided search approach for the calibration of building energy simulation models," *Energy Build.*, vol. 87, pp. 370–385, Jan. 2015, doi: 10.1016/j.enbuild.2014.08.052.

[51]