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SUSTAINABLE DESIGN APPROACH TOWARDS HOUSING DESIGN - OPTIMIZATION AND ENERGY PERFORMANCE ANALYSIS USING GREEN BIM & ASSESSMENT TOOL

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ABSTRACT

The population of India has increased during the past few decades. There is a severe dearth of infrastructure in India at all levels; this country's housing deficit is a major issue. The rapid urban expansion of 2.8 percent between 2001 and 2011 led to an increase in urbanisation from 27.8 percent to 31.2 percent, making the housing scarcity discussed in this study more important in urban centres. India has 1.2 billion people, 377 million of whom live in metropolitan areas.

The city's limited resources are under excessive pressure as a result of rapid urbanisation. There is now an acute shortage of many necessary amenities, including clean drinking water, a functioning sewage system, sanitary facilities, roads, and trash disposal. Water bodies and vegetation have been destroyed as a result of rapid urbanisation. The aim of this paper is to determine the Critical Success Factors (CSFs) in achieving Sustainable Housing Scheme from the economic, environmental, and social sustainability using various futuristic tools.

KEYWORDS: Sustainable housing, Green building, Climate adaptive design, Sustainable facade, Energy efficiency, Assessment tool, Building information modelling (BIM).

I. INTRODUCTION

Sustainability is the only option available to reduce the worst effects of growing urbanization. The generalisation, design, and usage of structures that serve as a guide for the development of housing are discussed in this paper in relation to sustainability principles. With limited proactive approaches and solutions, this study seeks to enhance the user experience, lessen negative effects on natural resources, and lower environmental expenses.

In order to face the problems of long-term management of the environment, sustainability must be incorporated into a vision for housing on a worldwide scale. Basic concepts can serve as creative guidelines for achieving sustainability, allowing open-source home designs to be customised to each distinct site according to the demands and preferences of individuals and regional natural systems.

This paper talks about how software applications have influenced and improved the construction sector. As a result, during the past 50 years, a wide range of building energy simulation (BES) analytical tools have been created, improved upon, and used throughout the building energy community. Building information modelling (BIM), one of the most recent developments, has drawn a lot of attention due to its influence on sustainable development and the possibility it offers for the industry to create energy analysis software.

1.1 AIM

The aim of this paper is to study sustainable built housing community which reunify humans and nature by sustainable approach applied with a design-purpose to improve on higher living standards of people and evaluation of its efficiency using futuristic tools.

1.2 OBJECTIVE

(a) To study different Criteria's, Factors, domains and the general principles of sustainability and the application of these principles of design in creating sustainable housing.
(b) To study and understand about different climates and their climate adaptive strategy for various temperate climatic zones in India and various passive design techniques to attain sustainable design.
(c) To study different techniques of high performance sustainable facade and analyzing their characteristic to achieve it.
(d) To analyze various futuristic sustainable design assessment tools which is used for assessing the sustainability performance of planning and design.
(e) To understand the optimization and process of building energy efficiency analysis based on BIM and energy-saving effect evaluation method for green building based on BIM.

1.3 SCOPE

This paper examines several design techniques and their impact on the sustainable housing community and evaluates using futuristic design assessment tool in order minimise and eventually eradicate the adverse impacts that buildings have on ecosystems and people's health while incorporating the entire lifespan of the building.

II. CRITERIA OF SUSTAINABLE HOUSING

Sustainability housing programs must continually assess financial viability, social and cultural acceptability, technical reliability, and compatibility with the surroundings in order to preserve their viability.

In order to reach a high quality of sustainability and green living, human rights must also be taken into account by other factors, such as location and surrounds, communication and transportation, and security and comfort in one's home.

(a) Physical building
(b) Site & Surrounding
(c) Quality of housing
(d) Human behavior
(e) Energy
(f) Culture & Values
(g) Waste & Water
(h) Communication & Transportation
(i) Cost & Availability

Through the development and implementation of ten sustainable housing criteria based on environmental, economic, and social factors, sustainable practices are produced on a housing scale.

III. STRATEGIES FOR CLIMATE ADAPTIVE HOUSING DESIGN

When designing, the context should be taken into account as the most crucial factor, and the location and climate of the area are of highest significance.

Table 1: The 20 Aspects of the design process for climate-responsive building design.

Source: Aste et al. (2014)

1. Landform: topography and slope orientation	7. Plan Form	12. Fenestration pattern and Configuration	18. Internal layout and partitions
2.Vegetation type and pattern	8. Plan Elements	13.Fenestration orientation	19. Internal materials
3. Water bodies	9. Building orientation	14. Fenestration Controls	20. Internal finishes
4. Street widths and orientation	10. Surface area to volume ratio	15. External Colours and textures	
5. Open spaces and built spaces	11. Roof Forms	16. Roof materials	
6. Ground Character		17. Walls	

In the process of designing buildings that are climate-responsive, Arvind Krishan divided the design process into 20 elements of the building as shown in Table 1 and the built environment in a sequence from macro-level features to micro-level aspects, wherein climate as a parameter is taken into account at every stage at every point.

3.1 STRATEGIES FOR VARIOUS ZONES BY CLIMATE CONSULTANT SOFTWARE

Each of India's climatic zones has data that can be taken from psychometric charts for individual cities as shown in Table 2, that can be examined on the climate consultant software which is used to analyze the current climatic conditions and it provides the indicative design strategy.

Table 2: Indicative strategies extracted from Climate Consultant 6.0 for the 5 climatic regions of India.

Source: Adapted from Climate Responsive Strategy Matrix for Designing Buildings in India research paper

Climatic Zone	Representative City	Conditions & Indicative Design Strategy
Cold Climate	Shillong	11% is the comfort conditions without reliance on any mechanical means , while through incorporation of passive means it can be made 70% comfortable through out the year.
Composite Climate	Delhi	Through passive techniques, indoor temperature can be made 52% for human comfort condition while the prevalent climatic conditions indicate only 14% comfort
Hot and Dry Climate	Ahmedabad	17% in the human comfort zone, building design required to moderate natural conditions to make indoors comfortable without mechanical support. High heat, strong solar radiations and low water content in the air to be dealt in design
Warm and Humid Climate	Chennai	2.2 % of prevalent conditions lie in human comfort zone and majority of the time the design needs to create an comfortable ambient atmosphere to reduce moderate high humidity, high temperature.
Temperate Climate	Bengaluru	26% the natural environment is in the human comfort level and through passive means 94% can be made brought to comfort level through out the year.

3.2 CONTROLLING FACTORS FOR CLIMATICALLY ADAPTIVE DESIGN

The 18 aspects from the Table 1 has been distributed under four groups of parameters as shown in Table 3. Aspects include everything from the structure's finishing to the site's local surroundings.

Table 3: Parameters of climate adaptive design.

SITE MICRO CLIMATE	BUILDING FORM & MASSING	BUILDING ENVELOP	BUILDING FINISHES
1. Topography & Orientation	1. Built form & Open space	1. Walls	1. External color & Texture
2. Vegetation Pattern	2. Plan form	2. Roof material	2. Internal material, finish
3. Street width & Orientation	3. Plan elements	3. Fenestration pattern	
4. Ground Character	4. Surface & Volume ratio		

3.2.1 SITE MICROCLIMATE

(a) Vegetation pattern - The site should be well vegetated with trees and plants to shade.
(b) Water bodies - Water body should be planned within the site to enable cooling and enabling the wind to carry cool breeze into the building.
(c) Ground character - Site should have a balanced softscape and hardscape.
(d) Street width & Orientation - Should be narrow with North-South oriented and the streets should be shaded.

3.2.2 BUILDING FORM AND MASSING

(a) Built form & Open space - More open planning are encouraged for thermal comfort.
(b) Plan form - Planned in such a way that it has minimum heat gain by minimum perimeter to area ratio.
(c) Plan elements integration - Should have roof gardens, fenestration with shading mechanisms, and shaded courtyards.
(d) Building orientation - Form should be oriented in such a way that longer side of the building facing North and South to minimize heat gain.
(e) S/V Ratio - Should have minimum S/V ratio.
(f) Roof form & Overhangs - Should be planned in such a way that it has Light roofs with deep overhangs.

3.2.3 BUILDING ENVELOPE

(a) Fenestration pattern & Configuration - Designed with large well shaded openings and fenestration should be sealed.
(b) Fenestration orientation - Fenestration should be oriented North facing.
(c) Fenestration control & Walls - Planned with low U-factor walls to reduce heat loss. Trombe walls, vent-equipped trombe walls, solar walls, and water walls and Operable windows.
(d) Roof material - For roof, Material with low U value should be used.

3.2.4 BUILDING FINISHES

(a) External colors & Textures - Exterior colors and texture shall be light/dark and Smooth/Rough.
(b) Internal materials & Finishes - It can be light/dark.

IV. DESIGN OF HIGH PERFORMANCE BUILDING FACADE & OPTIMISING WITH BIM & ASSESSING TOOL

The energy consumption and comfort levels of any structure are significantly influenced by the facade. High-performance sustainable facades are exterior structures that utilize the least amount of energy to provide interior atmosphere that encourages the occupant's productivity and well-being.

A facade must perform a variety of tasks in order to give its occupants a comfortable environment, including giving them views of the outdoors, withstanding wind loads, supporting its own dead load weight, letting in daylight, preventing solar heat gain, shielding them from external noise and extreme temperatures, and preventing air and water penetration.

4.1 BASIC TECHNIQUES FOR CREATING HIGH-PERFORMANCE SUSTAINABLE FACADES INCLUDE

(a) Adapting the building's geometry and massing in response to the location of the sun.
(b) Use of solar shading to reduce cooling demands and increase thermal comfort.
(c) Natural ventilation is used to improve air quality and lower cooling demands.
(d) Maximizing outer wall insulation and day lighting to reduce energy consumed for artificial lighting, mechanical cooling, and heating.

4.2 CATEGORIES OF FACADES

(a) Opaque facades - Mostly made of solid layers like masonry, stone, precast concrete panels, metal cladding, insulation, and frame. Additionally, windows or punched openings may be seen on opaque facades.
(b) Glazed facade - It mostly include storefront & Curtain wall made of transparent or translucent glass.

4.3 CHARACTERISTIC OF HIGH-PERFORMANCE BUILDING FACADE

TEMPERATE CLIMATE - Strategies for sustainable facade

(a) Solar control - Insulating of the facade from direct sunlight using self-shading forms that naturally shade it or other shading equipment.
(b) Reduction of external heat gains - Protection by utilizing opaque, well-insulated facade components.
(c) Cooling - Usage of natural ventilation when the surroundings and the building function allow.
(d) Daylight - Usage of daylight sources while reducing solar heat intake through the use of shading mechanisms and light shelving.

4.3.1 MATERIAL CHOICE

(a) Choosing the right kind of materials is crucial for creating sustainable facades.
(b) Designing for sustainable facades must focus on enhancing building exterior thermal performance and reducing thermal bridging.
(c) Material choices should be taken into account based on a material's embodied energy which has adverse effect on the environment.
(d) Measurements should be made based on area rather than mass or volume when comparing the embodied energy of facade systems.

4.3.2 THERMAL COMFORT

Thermal comfort is stated as "that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE, 2004). The six main factors that influence thermal comfort: air temperature, air movement, humidity, mean radiant temperature, occupants' metabolic rate, and occupants' clothing (Huizenga et al., 2006).

(a) Mixed mode of ventilation system can be used for the buildings that is facade opening or natural ventilation when the climate and environment are ideal, in combination with HVAC system when the climate is not ideal.
(b) The ideal WWR should be determined by a space's floor plan, the locations of its occupants, and the kinds of activities those occupants engage in.
(c) For areas where occupants are generally near to the windows, smaller WWRs should be employed, especially for south-facing facades.
(d) As the facade glazing also influences the thermal comfort of the occupants certain criteria's need to be considered such as the design of the glazing units, the glass's composition, and the efficiency of the shading devices employed with the window.

4.3.3 DAYLIGHT

(a) Lighting levels, daylight distribution, and protection from glare and direct sunshine are all important factors for designers to take into account when thinking about daylight and visual comfort.
(b) Perimeter zones can be planned with natural daylight and photo sensors to regularize artificial lighting and dimmers lower the HVAC system's cooling demands.
(c) WWR and orientation of the building are the main factors for the availability of the daylight.
(d) Light shelves should be provided where the daylight zone can be effectively and affordably expanded as in summers it directly blocks the sunlight which is redirected to the ceiling and penetrates deep within the space.
(e) Filtered, homogeneous, and glare-free daylight can be created using translucent glazing materials.
(f) Can be designed in such a way that it can increase day lighting by mixing translucent glass above and below with transparent vision glass at eye level while also providing views to the exterior.

4.3.4 HEAT AND MOISTURE MOVEMENT

A fundamental law of physics governs the movement of heat across facades: heat moves from higher to lower temperatures. One or more of the following processes result in this such as Conduction, Convection, Radiation, Air leakage.

(a) Design techniques for regulating heat flow include the use of a continuous thermal barrier (insulation layer), sealing air openings between the layers of materials to prevent conduction, providing a continued air barrier to avoid loss of heat through leakage of air, and preventing thermal bridging.
(b) The amount of air passing through a building envelope is decreased by installing air barriers as it regulates the airflow between the conditioned and unconditioned environments.
(c) As moisture movement is important factor in a sustainable facade, vapor barriers are designed to trap moisture or else it results in growth of mold which causes health effects on building users.

4.4 BUILDING PERFOMANCE & ENERGY EFFICIENCY ANALYSIS PROCEDURES USING ASSESMENT TOOLS

Overall Building energy analysis simulation are a crucial component of the design process for buildings that are both energy efficient and high performing because they aid in an examination of design possibilities and the evaluation of the carbon footprint and energy effects of design choices. The energy simulations using assessment tools like BIM are crucial components which helps in optimization of design for achieving energy efficient building. In order to evaluate and optimize the building performance, different analysis cycles should be part of an integrated design process (Punjabi & Miranda, 2005).

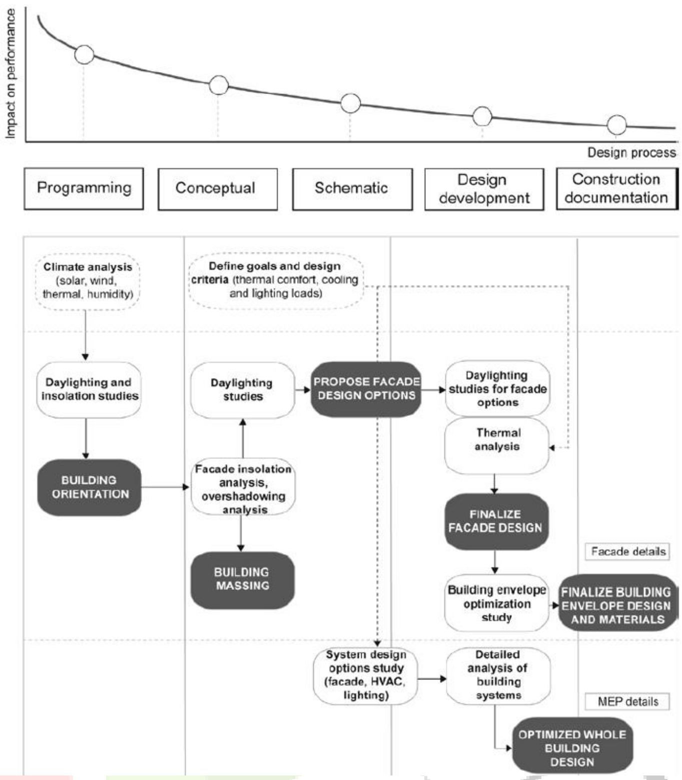


Figure 1: Framework for integrating the design of high-efficiency building envelopes with building performance analysis processes.

Source: Adapted by author from high performance building envelop

The fundamental performance analysis categories are depicted in Figure 1 in connection to the project stages, with an emphasis on building facade design. It is clear that contextual factors like climatic data, orientation, and building massing should be considered beginning with the programming process. The analysis next examines the entire sun shading approach suggested for the facade in alignment with nearby building's overshadowing during the conceptual stage. Different schemes for sun shadow and daylight analysis are should be performed and it should be optimized based on the best possible results. As shown in Figure 2 the size and position of windows are planned by the daylight stimulation analysis by feeding the location. In this building performance first stage would be the energy analysis and the second stage would be energy modelling as shown in Figure 3 which optimizes the size and prediction of mechanical equipment and estimation of annual energy usage. Through Revit a building model with all material specification is created which is going to stimulate the energy model which the energy consumption, Energy cost of the building.

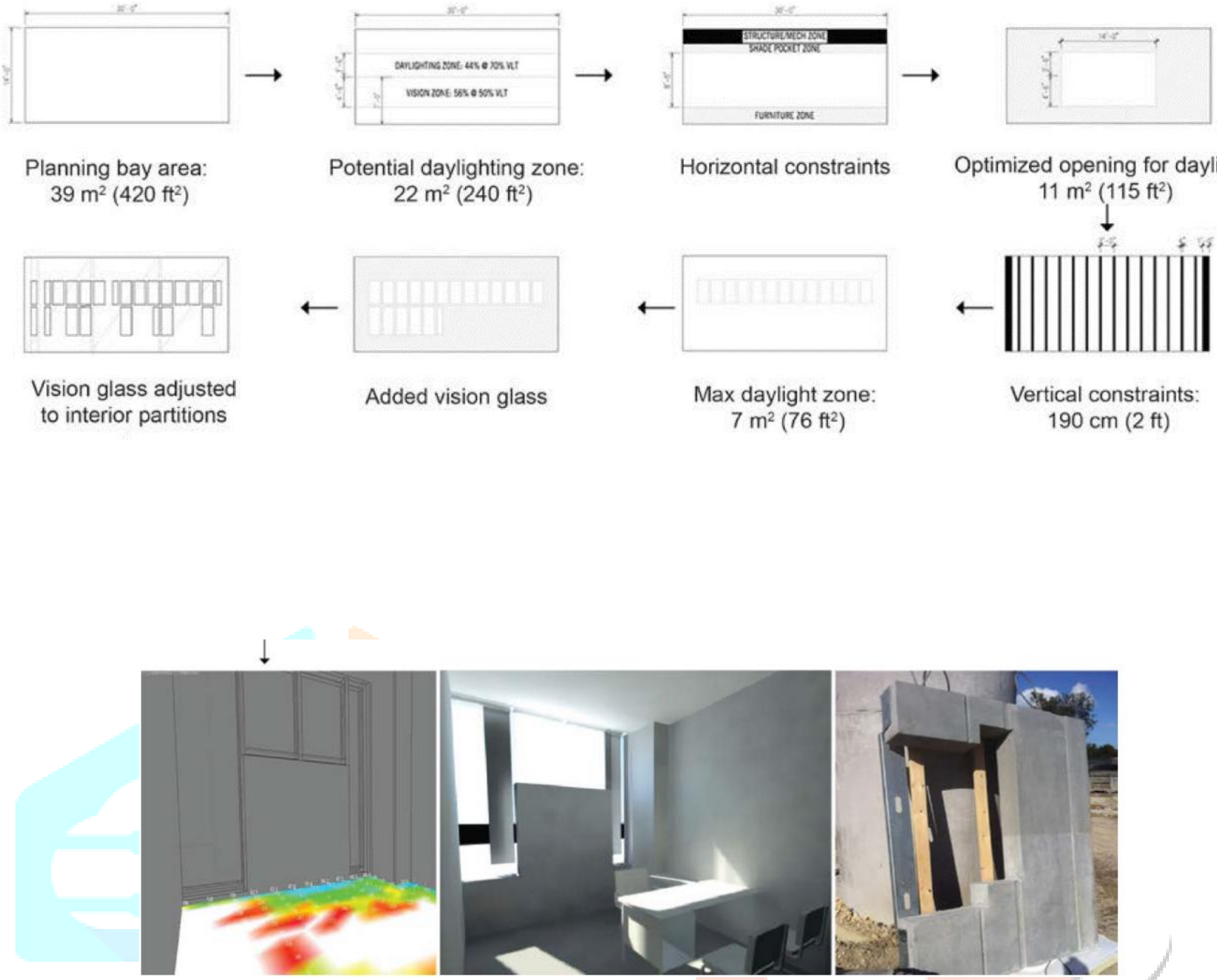


Figure 2: Utilizing daylight analysis to optimize the window patterns.

Source: Adapted by author from high performance building envelop

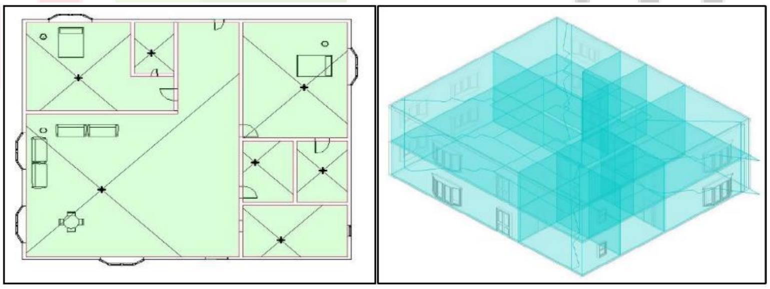
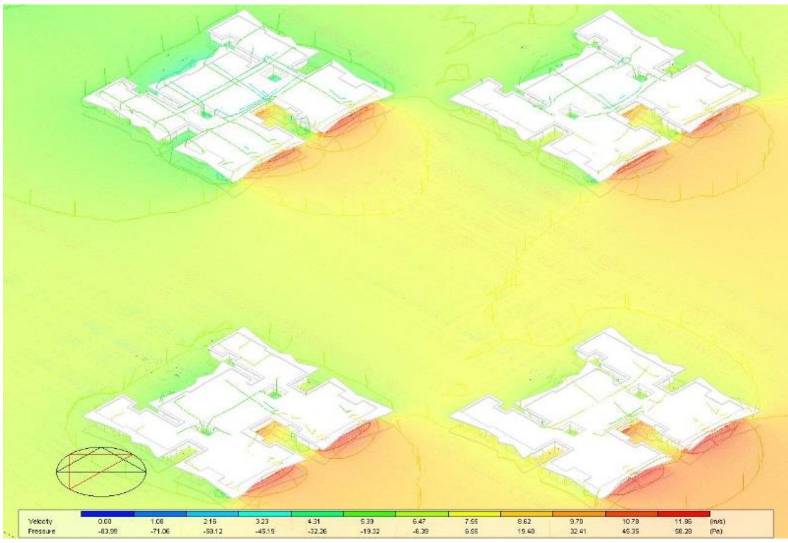


Figure 3: Energy model.

Source: Adapted by author from, Optimization and Performance Analysis of Residential Building for Sustainable Energy Design through BIM

Software programs with or without a BIM foundation can be used to do simulations and performance analyses. There are numerous tools and simulation software options with various modelling capabilities. There are different assessment tools for each design process. The concept and schematic design stage can be performed with Green Building Studio, Energy 10, Design Builder, and Ecotect. eQuest, Energy plus are used for schematic design stage. While BIM based application software are Green Building Studio, Ecotect. Design builder also gives us the external CFD analysis (Computational Fluid Dynamics) as shown in Figure 4, which is used for the building mass placement according to the existing wind movement. This analysis is done at a height of 20M from the ground to avoid obstruction. Daylight analysis can also be stimulated as shown in

Figure 5, based on the WWR been modelled or designed and by the stimulation results optimization can be made for the expected results. Various stimulations for thermal analysis, Solar analysis can also be performed.



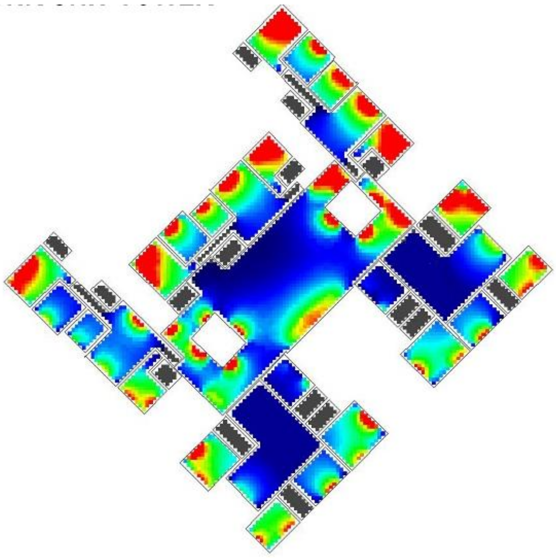


Figure 4: Computational fluid dynamics (Design Builder) Figure 5: Daylight analysis (Design Builder)

A breakdown of relevant simulation tools for the creation of high-performing, environmentally friendly building facades is shown in Table 4.

Table 4: Software for simulating building performance and its use in designing facades.

Source: Adapted by author from high performance building envelop

Simulation tool	Energy analysis	Energy modeling	Heat transfer analysis	Combined heat and moisture analysis	Daylight analysis	Thermal comfort analysis	BIM-compatible
Ecotect	+				+		Yes
Radiance					+		
COMFEN/ EnergyPlus	+	+					
eQuest	+	+					
Green Building Studio	+	+					Yes
CBE Thermal Comfort Model						+	
WINDOW			+				
THERM			+				
WUFI				+			

V. KEY INFERENCE

Through improved design in relation to location, building, operation, restoration, and the full building lifetime, sustainable housing aims to ensure that structures and their activities have the fewest negative impacts on human well-being and environmental conditions.

Since dwellings use a lot of resources and are the major source of global pollution, improving the application of energy-saving measures in housing is necessary.

One of the fundamental values of a sustainable architecture is the governance of water systems. Waste management on a housing population decreases illegal disposal and increases the amount of garbage retrieved and reduce the expenditures.

Sustainable housing practices must incorporate 10 criteria, including physical building, energy, water, site & surroundings, human behavior, quality of housing, culture & values, transportation, safety & comfort living, and price, which are obtained from three primary components: environment, social, and economic that encourages the well-being of people, sustainability, and protection.

Sustainable dwellings must enable communication over distances and aid in populace movement using green mobility.

The utilization of green construction materials is advantageous to the well-being of the residents as they are more resilient and are made from responsibly obtained and renewable resources.

As Energy efficiency is the major contributor of the sustainability which is influenced by the physical building and building facade contributes a major part which is dependent on climate, Occupant style, Building purpose.

From many green assessing software a variety of analysis and stimulations are extracted which optimizes the design and the green aspects like increasing the energy efficiency by analyzed placement of building form in site, reducing embodied energy and carbon from the built form, minimizing material waste and water efficiency.

VI. CONCLUSION

The main factor that promotes energy efficiency and makes thermally comfortable living spaces possible is the design of the building. The design procedures must be adequate and support the achievement of thermal comfort, hence lowering energy consumption. Reduced energy use and reduced environmental impact on physical buildings are prerequisites for sustainable development. Buildings use 40% of the total energy produced, which results in significant carbon emissions.

The climatic zone also affects how much energy is used by the building.

Studying and analyzing the various climatic zones and their effects would be necessary to design energy-efficient buildings in varied climates.

This also entails researching the usage of elements and materials that are both essential to sustainable development and climate-appropriate.

Understanding climate factors like temperature, sunlight rainfall, wind speed and direction, and humidity can help architects create sustainable buildings that are suited for each climatic zone.

With the use of digital prototypes, it is now possible to engineer and analyze every aspect of an assembly, from its physical and functional traits to its thermal behavior and manufacturing needs.

With the use of BIM and other assessment tools, better supply chain and customer collaboration are made which can result in more inventive green designs.

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