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A Simulation Based Study of Energy Conservation of Residences in Lahore, Pakistan.

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ABSTRACT

The role of residential sector is extensive with respect to overall energy consumption by construction industry. A house in composite climate of Lahore (Pakistan) needs intensive cooling in summers; as well as energy resources for ventilation to reduce humidity during monsoon and comfortable indoor temperature during winters. The objective of this research is to suggest means through which the comfort conditions of occupants in a house are fulfilled with a reduced load on mechanical resources. Recent trends in construction and design of residential buildings in Pakistan symbolize uncontrolled use of energy resources. There is no data available with planning and developing authorities of housing sector that shows an account of energy loads of built houses as having standards or codes. In this research the potential of energy conservation was therefore analyzed through smart sampling of various sizes of houses in a contemporary housing scheme in Lahore. A simulation-based study is used to establish potential conservation of energy resources consumed by houses as built with a projection to overall reduction in energy consumption by residential sector in Lahore; thereby showing a decrease in carbon emissions and achieving sustainability as well as environment friendly architecture.

Introduction

With the current fast depletion of energy resources and increasing environmental pollution, the importance of energy-efficient residential buildings should not be underestimated. Majority of modern buildings in this era consume large amounts of energy to maintain a comfortable indoor climate. The recent rapid urbanization has led to an increase in construction projects in Pakistan**.** The increasing trend of construction intensified the use of eco-friendly and energy saving architectural designs and techniques of buildings – the buildings which depend upon judicious use of energy resources. To learn about the energy audits of a residential building, its energy assessment if conducted through software, will suggest most appropriate means to cut energy uses and costs. Furthermore, to make existing structures as energy efficient, the suggestive use of insulation should be encouraged and adopted. In this regard, building envelope is the most effective element of a house, which if treated with correct techniques can make indoors comfortable for adaptive thermal comfort level of occupant, thereafter, efficiently cutting down energy loads.

RESEARCH DESIGN

In this research, trends of energy consumption of existing houses in Lahore were examined to develop an alternate model based on calculation of energy loads using ecotect software. Ecotect calculates various features of indoor climate in a precise manner, in addition to indicating immediate change in quality of indoor environment of a built space as a prompt response to any asserted changes in materials of construction through retrofitting or any other method.

The energy analysis of selected houses in this research revealed the potential for energy saving in the residential sector of Lahore, Pakistan. The expediency of computer software Ecotect for effective thermal analysis of selected houses is also described in this paper. A quantitative analysis of energy loads before and after insulation in selected houses is established to consequently derive the potential of saving energy for cooling/heating loads in the houses.

Building envelope broadly comprises of external walls, doors, foundation beds, roofs, and windows. The building envelope has a constant interaction with external environment. About fifty percent of the cooling load of residential buildings can be attributed to heat input or loss through the building envelope. The productivity of an effective building envelope is measured through its less dependency on mechanical services to maintain indoor climate of a house. The performance of insulation techniques involved in this research are, therefore, with reference to walls, roof, and windows.

Use Of Ecotect Software For Energy Analysis Of A Building

This software has integrated capabilities of analyzing consumption of energy, water, and carbon emissions. Ecotect enables architects to visualize and model the properties of buildings in their surroundings. The energy loads with variation in materials of construction are analyzed to calculate monthly cooling/heating loads of spaces.

To do so, the model of a building is developed through Ecotect and different areas with their titles are created. The doors and windows are inserted as secondary object, and subsequently materials or their specifications are inserted with modifications. The thermal properties can be adjusted, and various thermal analysis coefficients are calculated, such as internal gain and permeability. The energy loads for each month of the year can be calculated by entering values of above-mentioned attributes. The glazing, construction and weather data are required in Ecotect simulation as an integral need to calculate energy consumption by the building.

The significant features of Ecotect are calculations of heating, ventilation, and air-conditioning (HVAC) system used within a building. The software accurately calculates for comfort in passive buildings and energy loads for buildings with heavy dependency on mechanical systems as shown in dialogue box of Ecotect Operations in Figure 1 below:

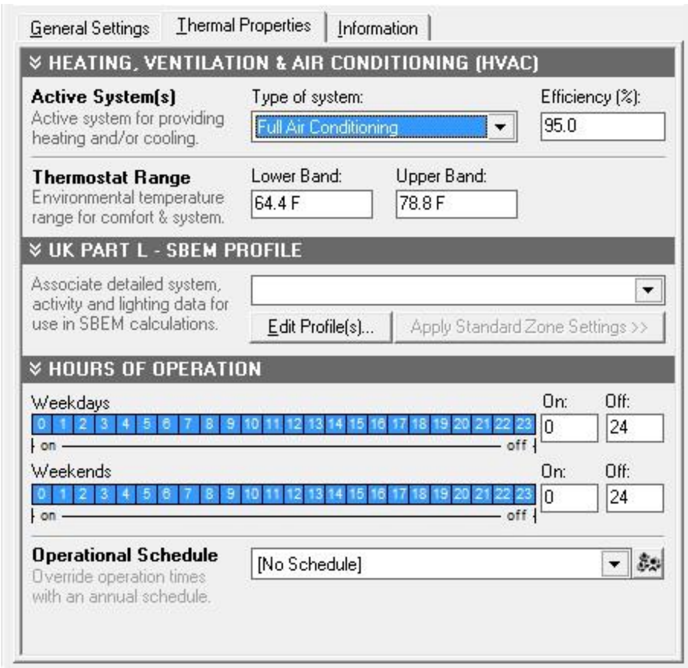

Figure 1: *Dialogue Box for Operations of Calculating Energy Loads through Ecotect*

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A set of internal operating conditions is allocated to thermal zone in ECOTECT. Occupants, heat emission from furniture, electronics, ventilation, thermostat temperatures, and infiltration rates in a space are included in the operating conditions for ecotect calculations. These conditions are observed on hour-to-hour variations throughout the whole year as for thermal analysis of selected case study house. The **Zone Management** for thermal properties in a particular zone of the house may be adjusted to **Full Air Conditioning** for analysis as shown in Figure 2:

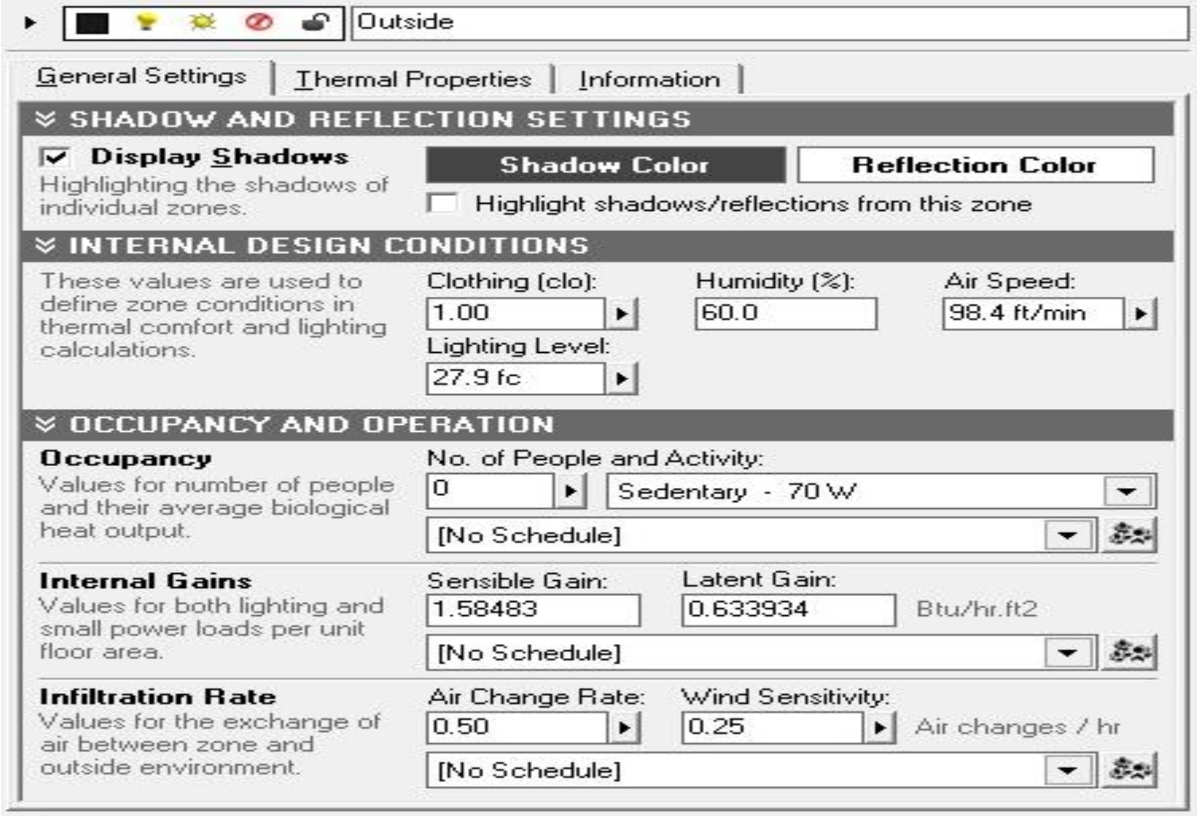

Figure 2: *Zone Management for Thermal Analysis of a Space in Ecotect*

Methodology & Contextual Data

1) To examine the trends of energy consumption of existing houses in Lahore, a group of residential units of 12 Marla size, in the residential scheme of Askari-10 of Lahore Cantonment, were selected. The composite climate of Lahore and location of Askari 10, being adjacent to the Lahore airport, are the factors specifically considered while improving indoor thermal comfort level of selected built houses in this scheme. As for the details of building envelope of selected houses, one wall is dead in case of these semi-detached houses in Askari-10 with almost three elevations having direct sunlight. Top roof slabs are constructed with bitumen, polythene, mud, and brick tiles, with no categorical specification for insulation.

2) The field surveys were conducted to gather trends of consumption of electricity in selected residential unit of 12 Marla in Askari-10. The electricity consumption was studied by collecting electricity bills of houses during extreme weather months i.e., June and January.

3) Thus, building envelope was analyzed for heat loss and gain to the base case buildings. The materials used in building envelope of houses were examined for energy efficiency. Ecotect Software laid down comparative analysis between electricity consumption of houses before and after use of recommended building materials with variation in their specifications.

4) The recommended insulation materials for building envelope were suggested to meet objective for reducing the usage of electricity for cooling and heating loads of the house thereby effectively improved thermal comfort of selected houses. The physical and chemical behaviors of suggested materials of construction are also important domains and have been explained in section of analysis of base case houses in this research. The single instances of houses constitute the basic methodological tools to generate final analysis.

Before conducting the field surveys the following contextual information also needed careful attention:

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Climate of Lahore

There are five varying seasons in Lahore: foggy winters (November–February), Spring (February–April), Summers (April–June), Humid Hot Monsoon (July–September), and Dry Autumn (October–November). June is the hottest month in Lahore. The composite climate of Lahore makes it very challenging for architects to design and propose a mechanism of building design and materials of construction to achieve adaptive thermal comfort in response to the diversity in climatic conditions during the five seasons in Lahore.

Details on the climate data of Lahore is available from the Pakistan Metrology Department:

Temperature

Average dry bulb temperature in Lahore varies throughout the year, between 40^{o}C (105^{0}F) in June and 6^{o}C in January and December.

Relative Humidity

The average relative humidity in Lahore is about 38.6% and average monthly relative humidity ranges from 30% to 59% in August.

Annual Precipitation:

Average rainfall in Lahore is 489.00 mm, which is equivalent to an average monthly rainfall of 40.75mm (1.60 inches). During July the average precipitation level is 288 mm of rain falls over a period of 9 days. While in November, only 1 mm of rainfall over less than 1day is observed.

Annual Wind Speed:

The average wind speed in summer is about 3.1metres/second and 2.4 meters/second in winter.

Annual Wind Direction:

During October to May wind direction in Lahore are commonly northwest. On the contrary it is southeast during June to September. This southeast direction causes rainfall in region.

Criteria For Selection Of Residential Buildings

Askari-10 fairly represents the contemporary society housing pattern of Lahore (Figures 3 & 4). Many residents are army retired personnel who were allotted accommodation after their retirement from the forces, and therefore, represent a middle income and educated group of the society. The houses are uniform in design and usage, and do not particularly depict any specific energy efficient techniques or design features, henceforth, houses of various categories as defined by the difference in their sizes were selected for this study.

Figure 3: *Master Plan of Askari-10. Source: ASK-X Housing Office*

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Figure 4: *Main Boulevard Road of Askari-10. Photo by authors*

BASE CASE HOUSES IN ASKARI-10

In examining the selected 12-Marla house (Figures 5 & 6), primary area of analysis was thermal performance of building envelope with respect to length of varying seasons. Therefore, the energy load of these houses provided pattern of heat transfer from outdoors to indoors for houses to be built in future in Lahore.

The study of these houses furnishes a clear and well-defined demand of reduction in cooling/heating loads. The internal layout, functional zoning, and building envelope specifications of houses were considered for calculating current consumption of electricity for cooling the spaces in summers.

Figure 5: *A View of 12-Marla Houses Lane. Photo by authors*

Figure 6: *Front Elevation of 12-Marla House. Photo by authors*

CASE I

Project Description of Base Case House - I

The house as constructed in 2007 with front elevation as southwards covers area of 1873 ft on ground and 1073 ft on first floor. The By-Laws for houses in Askari-10 relate to have 8’-00” green belt on the front side, 5’-00” passage on sides and 5’-00” on the back (Figure 7).

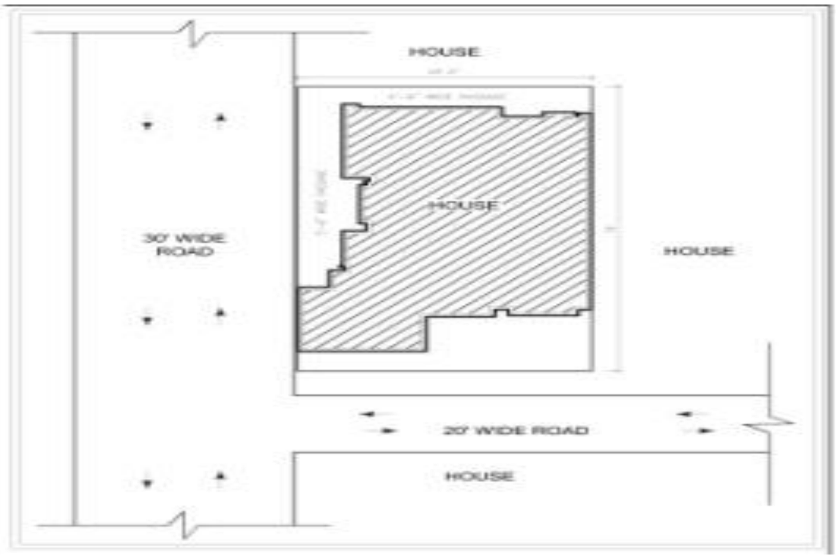

Figure 7: *Site Plan of 12-Marla House Source: ASK-X Housing Office*

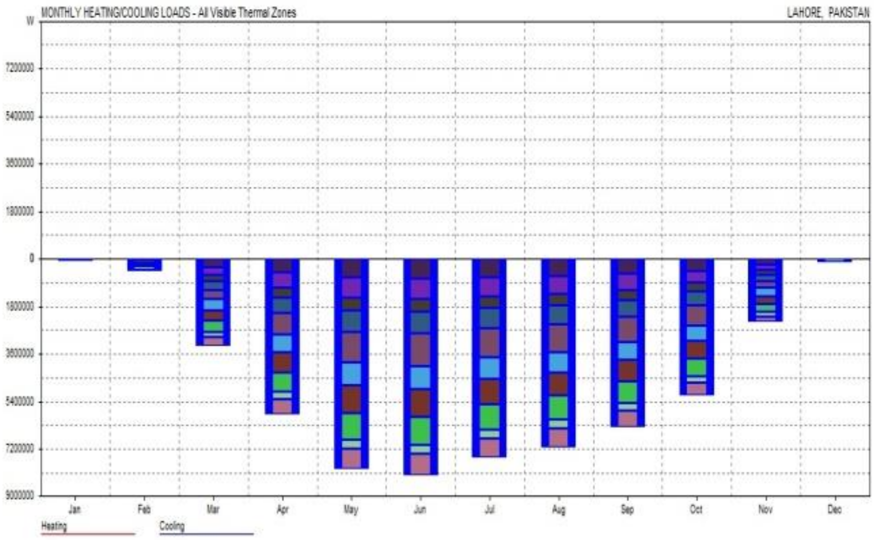

Figure 8: *Graph of Monthly Heating/Cooling Loads, 12 Marla House, Case-I analysis on Ecotect*

The bars of graph in Figure 8 show monthly energy consumption of the house. Crimson bars represent heating loads and blue bars represent cooling loads of residential building. Different color boxes on these bars represent the shares of different zones in energy consumption. The blue bars depict high average of cooling loads tolerated by the house. Cooling load is maximum in months of June, which is 8198292W, and remains zero in the month of January and December (Figure 9). The specifications and modifications as suggested in later part of this research has shown consequently a considerable reduction in these cooling loads.

MONTHLY HEATING/COOLING LOADS			
All Visible Thermal Zones Comfort: Zonal Bands			
Max Heating: 0.0 C - No Heating			
Max Cooling: 19703 W at 15:00 on 9th June			
	HEATING	**COOLING**	**TOTAL**
MONTH	**(Wh)**	**(Wh)**	**(Wh)**
Jan	0	82426	82426
Feb	0	456375	456375
Mar	0	3324463	3324463
Apr	0	5906923	5906923
May	0	7976832|	7976832
Jun	0	8198292|	8198292
Jul	0	7558941	7558941
Aug	0	7134416	7134416
Sep	0	6383198	6383198
Oct	0	5202768	5202768
Nov	0	2423718	2423718
Dec	0	120487	120487
TOTAL	**0**	**54768836**	**54768836**
PER M^2	**0**	**224047|W**	**224047**
Floor Area	**244.452M2**		

Figure 9: *Monthly Heating/Cooling Loads analysis on Ecotect for Base Case House-I (12-Marla House)*

Modification In Building Envelope Of Selected 12 Marla House

The thermal insulation in walls and roofs results in reducing the annual energy value in buildings. Additionally, it helps to improve thermal comfort inside the houses with reduced reliance on mechanical air-conditioning, particularly throughout inter-seasons periods. Nearly 60% of the thermal transfer happens through the roof and wall of a house. The emphasized insulation in buildings additionally brings extra edges in energy savings, leading to lower energy bills and protect the environment by cutting carbon dioxide emissions.

Modified Building Envelope Proposal-A: Materials for External Walls & Roof Insulation

The 11” thick cavity wall of brick with 2” air space for external wall combined with 2” thick polystyrene medium density for roof insulation is suggested for external walls of the selected 12-Marla House. Proposal A comprises A1 as roof modification and A-2 as the external wall details, described below:

A-1 Roof Modification: The material proposed for roof modification, titled as A1, is medium density 2” thick polystyrene to insulate the roof.

Polystyrene: The polystyrene in Lahore is commercially known as *Thermocole* and *Thermopore*. According to the ISO-PS standards, it is an aromatic polymer made from the monomer styrene, which is a liquid hydrocarbon obtained from petroleum in the chemical industry. As one of the most widely used plastics, it weighs billions of kilograms every year. The density of these panels ranges from 12 kg/m^3 to 45 kg/m^3, available in varying sizes of sheets and boards.

Polystyrene can either be a thermosetting polymer or a thermoplastic. A thermoplastic polystyrene is in a solid (glassy) state at room temperature but flows if heated above its glass-transition temperature T_g of about 100°C (for molding or extrusion) and becomes solid again when cooled. Pure solid polystyrene is a colorless, hard plastic with limited flexibility. It can be cast into molds with fine detail. Polystyrene can be transparent or can be made to take on various colors.

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A- 2 Wall Modification: The cavity wall insulation (Figure 10) is proposed as 11" thick brick cavity wall with 2" air space for external wall of selected houses. It is estimated that, in the case of an average grant aided installation, with the savings made on electricity bills, the insulation will pay for itself in under two years.

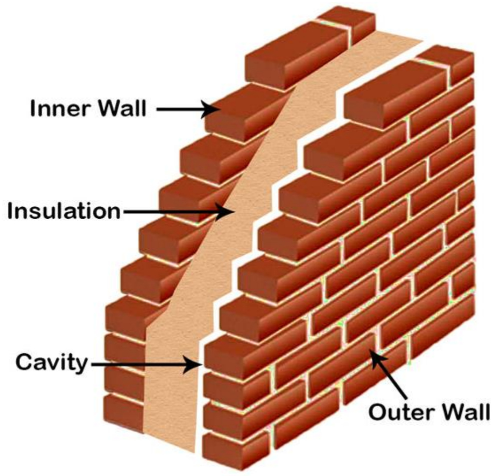

Figure 10: *Brick Cavity Wall with Insulation. Source: https://gharpedia.com/blog/cavity-wall-advantages-and-disadvantages/*

Reference lengthy hot season in Lahore, brick is a good choice in materials of construction for houses. More than 9" thickness of brick walls is good for reducing heat transfer from outdoors to indoors, has longer life cycle and results in low maintenance as exterior walls of a house. Also, the thermal behavior of brick, due to its porosity and bilinear interpolation of nodal temperature, render it as resistant to high temperatures.

Modified Building Envelope Proposal-B: Materials for External Walls & Roof Insulation

To minimize cooling loads of building another set of walls and roof specifications are proposed, based on locally available materials.

B-1 Roof Modification: Roof is proposed to be laid as 6" R.C.C Slab + Bitumen coat + high Density Polythene + Mud Pushka + Brick Tiles.

B-2 Wall Modification: 8" aerated-insulated concrete block wall with cement plaster of 3/8" on both sides of the wall is proposed for insulation of external walls of selected case study houses. An 8" hollow concrete block (the type used for most concrete block walls) only has an R-Value[1] of 1.11. EPS insulation blocks[2] that are 5" thick have an R-value of R-20.5. It is simple, inexpensive, and easily available. The R-value will be much greater for 10" or 12" block, as explained in Table 1 below, and will directly increase the capacity of concrete blocks to resist the conductive transfer of heat to indoors of house, and outlook of a concrete block. A capable level of thermal comfort is achieved by concrete blocks in houses during warm dry climate and the aesthetics of exterior of a house will also be enhanced as good as any other finishing materials for the exteriors of houses (see Figure 11).

BLOCK SIZE	BLOCK R-VALUE	EPS INSULATION BLOCK R-VALUE	COMBINED R-VALUE
8" Concrete Block	1.11	20.5	13.52
10" Concrete Block	1.2	29.07	19.04
12" Concrete Block	1.28	36.09	23.56

Table 1: Varying performance of hollow concrete blocks with reference to EPS & Unit R & combined R values

[1] The resistance of a material of construction to conductive flow of heat from outdoor to indoor of a building is R-value of the material.

[2] The EPS, explained as expanded polystyrene blocks, have their own resistance to heat penetration and later on when concrete is poured into these EPS blocks the R value is increased collectively.

Figure 11: *Exterior of a house with external walls made of concrete blocks. Photo by*

Conclusion

The increase in cooling loads in residences of Lahore, from March to September, are substantially reduced with proper use of insulation on building envelope having studied the trends of energy consumption in selected house in Askari-10. The energy audit through Ecotect for existing residential buildings is strategically important with integration of energy efficiency techniques, such as insulation to walls and roofs, to make the indoor climate of houses thermally responsive and comfortable for the occupants. Various combinations of building material specifications for building envelopes help reduce the energy consumption of residential buildings by minimizing the amount of heat entering the building. The quantitative comparisons in this research have shown that for building envelopes of different specifications, energy consumption can be reduced by up to 26%. The potential extra cost range for 1 inch thick insulation both in roof and wall varies within 6% to 10% of the acquisition cost of this special base case house situation and the payback period for this initial investment increase is about 2 years. The focus of annual energy saving is on high upfront costs. The cost of purchasing material specifications for an energy-efficient house may be higher than typical material specifications, but the cost of ownership is much lower, which can extend the lifespan period. Therefore, it is well concluded that the energy loads can be effectively reduced in the houses in Lahore through well-insulated building envelope and this trend of reduction in electricity will certainly result in overall decrease in electricity usage by residential sector in the country. To conclude the decrease in monthly electricity consumption of a residence achieved by using insulated building envelope establishes sustainability as well as environmentally responsive in performance of the building designs of houses.

References

Ahmad A., Zhao Y., Shahbaz M., Bano S., Zhang Z., Wang S., & Liu Y. (2015). Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. Energy Policy, 96, 131–143

Ali A., Khatoon S, Ather M., and Akhtar N. (2015). Modelling energy consumption, carbon emission and economic growth: Empirical analysis for Pakistan. International Journal of Energy Economics and Policy, 5(2), 624–630

Alshehry AS, and Belloumi M (2015). Energy consumption, carbon dioxide emissions, and economic growth: the case of Saudi Arabia. Renew Sust Energ Rev 41:237–247

Apergis N, Payne JE, Menyah K, and Wolde-Rufael Y (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecol Econ 69(11):2255–2260

Arouri MEH, Youssef AB, M'henni H, and Rault C (2012). Energy consumption, economic growth and CO_2 emissions in the Middle East and north African countries. Energy Policy 45:342–349

Balsalobre-Lorente D, Shahbaz M, Roubaud D, and Farhani S (2018). How economic growth, renewable electricity and natural resources contribute to CO_2 emissions. Energy Policy, 113, 356–367

Hanif I (2018). Impact of economic growth, non-renewable and renewable energy consumption, and urbanization on carbon emissions in sub-Saharan Africa. Environ Sci Pollut Res 25(15):15057–15067

Jebli MB, and Youssef SB (2015). Economic growth, combustible renewables, and waste consumption, and CO2 emissions in North Africa. Environ Sci Pollut Res 22(20):16022–16030

Khan M.K, Teng J.Z, Khan M.I, and Khan M.O. (2019). Impact of globalization, economic factors and energy consumption on CO_2 emissions in Pakistan. Science of the total environment, 688, 424–436

Pao HT, and Tsai CM (2010). CO_2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38(12): 7850–7860

Shahbaz M, Uddin G.S, Rehman I.U, and Imran K (2014). Industrialization, electricity consumption and CO_2 emissions in Bangladesh. Renewable and Sustainable Energy Reviews, 31, 575–586

Siddiqui R (2004). Energy and economic growth in Pakistan. Pak Dev Rev 175–200

Zoundi Z (2017). CO_2 emissions, renewable energy and the environmental Kuznets curve, a panel integration approach. Renew Sust Energ Rev 72:1067–107

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