International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 6, Issue 11, PP. 414-419, November 2019
https://www.ijew.io/
https://doi.org/10.34259/ijew.19.611414419

Feasibility Analysis of Green Technologies For Residential Buildings

Tayyaba Sony[1], Muhammad Jamal Farooq[2], Adan Zahid[3], Uzair Muhammad[4], Haseenullah[5]
[1,2,,3,4,5] Department of Electrical Energy System Engineering, US-Pak Center for Advanced Studies in Energy (USPCAS-E), UET, Peshawar, Pakistan
Tayyaba_sony@yahoo.com[1], engr.jamal.farooq@gmail.com[2]
Received: 17 October, Revised: 25 October, Accepted: 29 October

***Abstract*—** Pakistan is suffering from acute energy crisis since last decades. There is a big gap between power supply and demand and the shortfall is about 5000 MW per day. This shortfall is badly affecting all sectors which consumes electricity like residential, commercial, industrial and agriculture etc. Among the total energy about 43 % is consumed by the residential buildings. This high consumption needs to be minimized so finding desirable and effective ways to minimize the energy consumption of existing residential buildings and to propose strategies that are energy efficient is the aim of this research work. Each household has its own energy consumption pattern which is affected by the socio-economic conditions, number of occupants, the age group and gender. Thus, figuring out a generalized procedure for the transformation of residential buildings into the energy efficient building becomes very challenging. The proposed methodology aims at optimizing the energy consumption of residential buildings and finding a generalized procedure that can be adopted to transform any residential building into a low energy building. The test site selected for the proposed work is situated at canal town Peshawar which is a residential building. To lower down the electricity consumption of the selected building different insulation materials and energy efficient equipment's along with different retrofitting strategies are analyzed in this research work. The financial analysis is also carried out based on the KWH savings, with an improvement in energy consumption up to 30%.

***Keywords*—** LEB, Retrofitting, Energy Efficiency, Green technologies.

I. INTRODUCTION

Energy is essential to any society because of its critical role for social and economic development besides the improved standards of living in the world [1]. Due to increasing population of the world the global demand of energy is rapidly increasing as the time is passing. Pakistan is also facing the severe energy crisis since last decade. This energy crisis has seriously hampered the economic growth and development progress.

In Pakistan there is shortfall of electricity, there exists big gap between supply and demand that has caused load shedding in rural and urban areas. There is a need of total of 20,223 MW of electricity per day in the country while the supply is less than the demand which is 15,700 MW per day, hence the country is facing a shortfall of approximately 5000 MW per day due to inadequate supply [2]. Due to this shortfall the electricity load shedding occurs for about 8-10 hours in urban areas and 15 hours in rural areas, which is badly affecting all spheres of life [3]. To overcome this shortfall we need to both increase the generation of energy as well as optimize the energy consumption. Every year the national demand for the electricity increases and hence the associated cost also increases, there is a need to minimize the existing energy consumption in an efficient way, so that the end consumer will fulfill their energy requirements at minimum price.

In Pakistan, electricity is consumed by various sectors as shown in fig 1. As it is can be seen from the figure that most of the energy is consumed by building sectors, which is about 43%. This high consumption of electricity needs to be minimized. There are different building types in Pakistan i.e. industrial, commercial and residential etc [3]. In this propose research work, the aim is to analyze the energy consumption of existing residential buildings and to propose strategies that are energy efficient so that the energy consumption is minimized. In residential buildings the average annual energy consumption is approximately 150-230kwh/sq.-m [4]. There is no standard characterization of Residential buildings with respect to energy ratings in Pakistan. National energy efficiency and conservation authority (NEECA) and Pakistan Engineering council (PEC) has devised codes for commercial buildings not for Residential buildings.

Most of the Residential buildings are built based on poor energy conservation based on space heating requirement. There is a need for an investigation, which can provide some mechanism to characterize the energy profile of residential buildings w.r.t space heating requirements and a mechanism to somehow generalize it based on some pre-defined parameters.

The cost of Retrofitting of a Residential building to transform it to energy efficient building is very high, so the proposed strategy aims to reduce the annual space-heating requirement based on energy efficient technologies and also calculating the payback period of the project. In the proposed study, I have

considered the analysis of a residential house of covered area of 138sq-m consisting of two bedrooms, two washrooms, kitchen and six occupants. The house on average requires the annual electricity consumption of 2548Kwh units (data collected from actual utility bills).

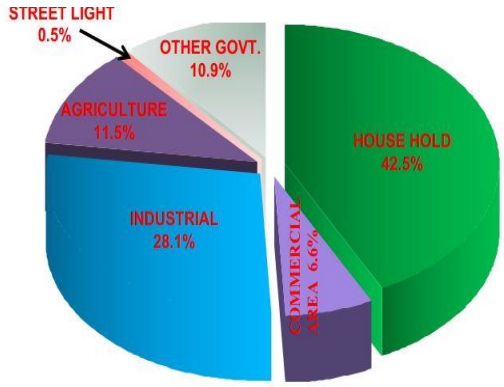

Figure 1 Consumption of electricity in various sectors of Pakistan [3]

II. ENERGY EFFICIENT BUILDINGS

Energy Efficient buildings are those buildings that consumes considerably less energy than normal buildings. Energy efficient buildings are mostly based on passive techniques such as building site selection, orientation, windows number and position, material used in façade of the building, skylights, green roofing, shading devices [5]. To remodel or reconstruct an existing building into an energy efficient building is called retrofitting. Retrofitting of an existing building costs more than building a new one. A fundamental goal of retrofitting is to reduce the energy requirement for space heating without effecting ambience requirements to achieve human comfort[6]

III. NET ZERO ENERGY BUILDINGS

A net zero energy building is a building that has zero energy consumption and carbon dioxide annually [6]. Residential or commercial building may fall under net zero energy buildings if they have significantly minimized their energy requirements by adopting energy efficient technologies or through renewable energy technologies.

IV. EQUEST SOFTWARE

The eQuest software is an open source software. It calculates the buildings total energy consumption on hourly, monthly and annual basis.

V. SYSTEM COMPONENTS

A. Insulation Material

Insulation of the building has significant potential to minimize the consumption of electricity. In first step the building was analyzed for two different insulation types i.e. polystyrene and polyurethane the results were in favor of polystyrene as described below. Thermally insulated model consists of polystyrene foam with different arrangements that has applied to the rooms. There are basic three models designed with polystyrene, which can be incorporated in the analysis phase so that the results from the analyses can be different from one another. These three models have insulations with on different locations, i.e. insulation on the outer face of the wall which is termed as external insulation, insulation on the inner face of the wall which is termed as internal insulation and the combination of the internal and external insulation which is termed as mixed insulation.

B. Energy Efficient Appliances

By incorporating the energy efficient appliances, the energy consumption can be definitely low down as compared to the conventional appliances, so in this model the energy efficient appliances were considered and reduction in the energy consumption was noticed.
In this model the tube lights are to be replaced with energy saver bulbs or LED, conventional AC with inverter type etc.

C. Combination of Insulation Material And Energy Efficient Appliances

In this technique as the name suggests combination of insulation that is polystyrene and energy efficient appliances was proposed. A significant reduction in consumption of electricity was observed.

VI. SYSTEM CONFIGURATIONS

The residential building was analyzed for different energy efficient strategies in the form of different scenarios. All these scenarios are discussed below.

A. Scenario-I Insulation Using Polystyrene

In this model polystyrene is used against the 8-inch brick having 0.25 inch mortar on both sides. This insulation arrangement is same both for wall and roof. Arrangement is given below in table 1.

TABLE 1 WALL MATERIAL USING POLYSTYRENE

1	Cement mortar 0.25 inch
2	Common brick 8 inch
3	Polystyrene 3 inch
4	Cement mortar

B. Using Energy Efficient Appliances

As the conventional electric appliances consumes a significant amount of electricity so it is better to use energy efficient appliances as these appliances definitely reduce the consumption of electricity. The tube lights which are in use in the house to be modeled is of 60 watts that can be replaced by energy saver that consumes only 25 watts, similarly Air condition which is in operation in the house is conventional AC that is to be replaced with inverter type AC to reduce consumption of electricity. All other conventional appliances can also be replaced with energy efficient appliances. The e quest software manipulates all these information of energy

efficient appliances in the form of W/sq. ft., which is reduced in case of using energy efficient appliances.

C. *Scenario-III Insulation using 1-inch Internal Polystyrene with EEA*

In this model internal insulation of polystyrene that is 1 inch is applied on the wall and roof and also using energy efficient appliances. The arrangement of insulation for wall is given below in table 2.

TABLE 2 WALL MATERIAL USING INTERNAL 1-INCH POLYSTYRENE

1	Cement mortar 0.25 inch
2	Common brick 8 inch
3	Polystyrene 1 inch
4	Cement mortar 0.25 inch

D. *Scenario-IV Insulation using 1.5 inch internal polystyrene with EEA*

In this model one and half inch polystyrene is applied internally on the wall and roof of the building and also using energy efficient appliances. The composition of the wall is given in the table 3 below.

TABLE 3 WALL MATERIAL USING 1.5-INCH POLYSTYRENE INTERNALLY

1	Cement mortar 0.25 inch
2	Common brick 8 inch
3	Polystyrene 1.50 inch
4	Cement mortar 0.25 inch

E. *Scenario-V Insulation using 3 inch internal polystyrene with EEA*

In this model 3-inch polystyrene is applied internally to the wall and roof and also considering energy efficient appliances in the rooms. The composition of the wall is shown in the table 4 below.

TABLE 4 WALL MATERIAL USING INTERNAL 3-INCH POLYSTYRENE

1	Cement mortar 0.25 inch
2	Common brick 8 inch
3	Polystyrene 3 inch

F. *Scenario-VI Insulation using 3 inch polystyrene external with EEA*

In this model three-inch insulation is applied externally and also using energy efficient appliances. In external insulation polystyrene is applied before brick. The composition of wall is shown in table 5 below.

TABLE 5 WALL MATERIAL USING EXTERNAL 3-INCH POLYSTYRENE

1	Cement mortar 0.25 inch
2	polystyrene 3 inch
3	Common Brick 8 inch
4	Cement mortar 0.25 inch

G. *Scenario-VII Mixed Insulation with EEA*

In this model both internal and external insulation is applied which is termed as mixed insulation. In this type of insulation polystyrene is applied on both sides of the brick and then covered by cement mortar. Also energy efficient appliances are used along with mixed insulation. The wall composition is as shown in table 6 below.

TABLE 6 WALL MATERIAL USING MIXED INSULATION

1	Cement mortar 0.25 inch
2	polystyrene 3 inch
3	Common Brick 8 inch
4	polystyrene 3 inch
5	Cement mortar 0.25 inch

VII. RESULTS

This section deals with results obtained as simulations and analysis were done for seven different scenarios. All these results are briefly described below in the form of different scenarios.

A. *Scenario-I Insulation using polystyrene*

When polystyrene is applied on the walls and roof of the rooms the total annual energy consumption reduced to 1965 kWh. The simulation results shows almost 23% decrease in total energy consumption per year. The following figure 2 shows the comparison between baseline case and scenario-I.

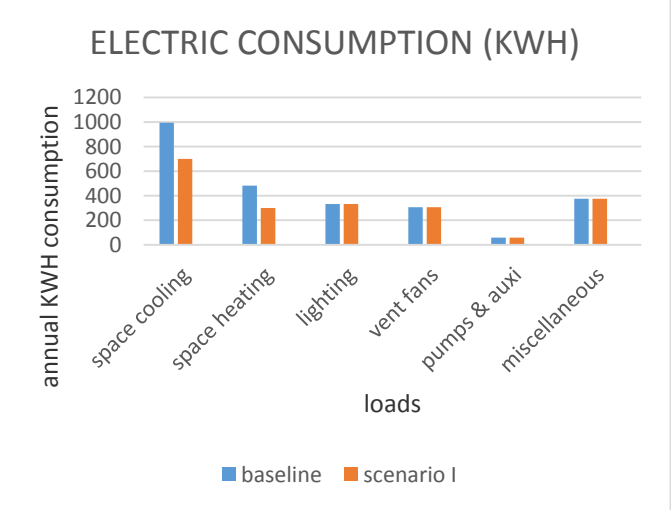

Figure 2 Comparison between Baseline and Scenario-I

B. *Using Energy Efficient Appliances(EEA)*

When Energy Efficient Appliances (EEA) were proposed, the total annual energy consumption reduced. The consumption of energy reduced to 1971 kWh units. The following figure 3 shows the comparison between baseline case and scenario-II.

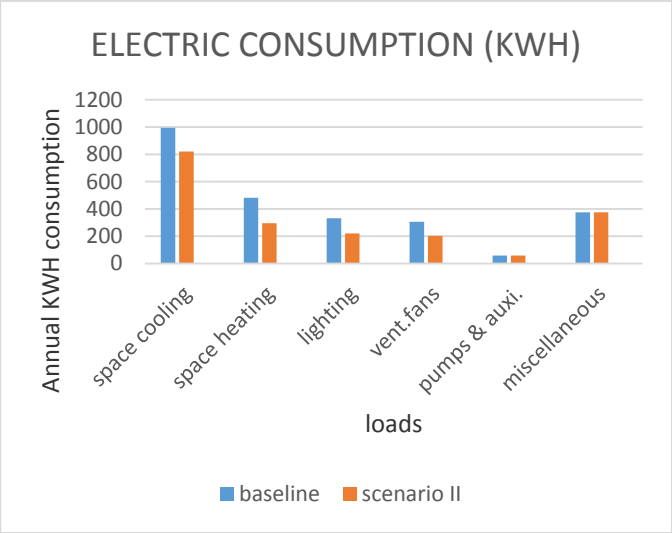

Figure 3 Comparison between Baseline and Scenario-II

C. *Scenario-III Insulation using 1-inch internal polystyrene with EEA*

When one inch expanded type of polystyrene was applied internally and also proposing EEA
The total consumption of electricity reduced to 1789 Kwh units. The following figure 4 shows the comparison between baseline case and scenario III.

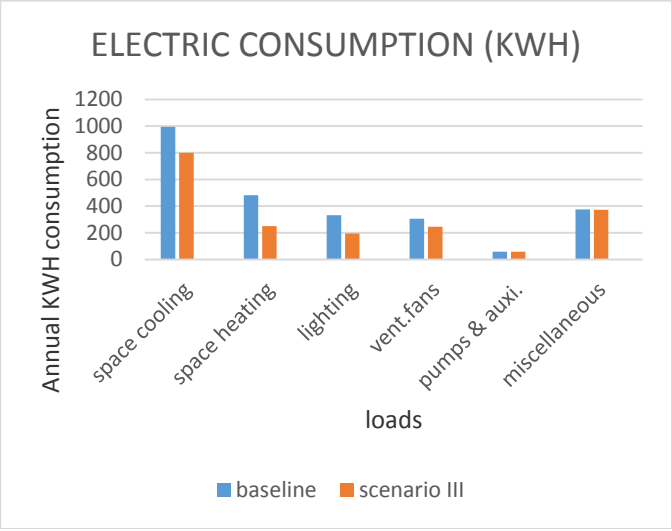

Figure 2 Comparison between Baseline and Scenario-III

D. *Scenario-IV Insulation using 1.5 inch internal polystyrene with EEA*

In this model when one and half inch expanded type of polystyrene was applied along with considering EEA the total consumption of electricity reduced to 1724 kWh units. The following figure 5 shows the comparison between baseline case and scenario IV.

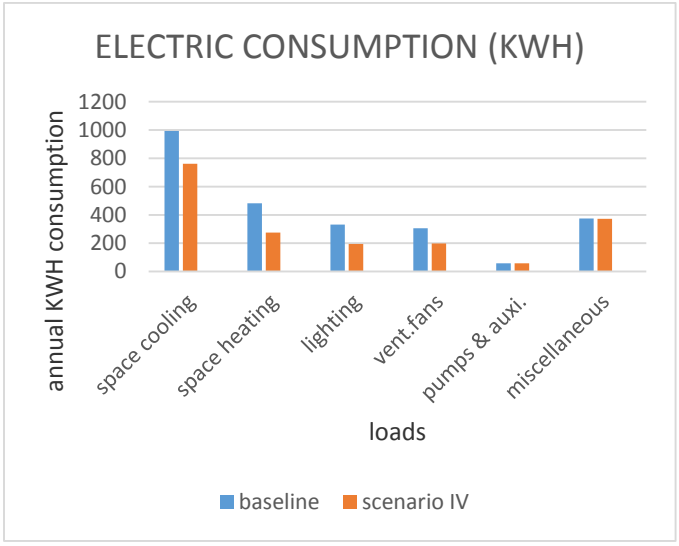

Figure 5 Comparison between Baseline and Scenario-IV

E. *Scenario-V Insulation using 3 inch internal polystyrene with EEA*

When three inch expanded type of polystyrene was applied along with considering EEA, the consumption of electricity reduced to 1681 kWh units per year. The energy consumption decreases as the thickness of the insulating material increases. The following figure 6 shows the comparison between baseline case and scenario -V.

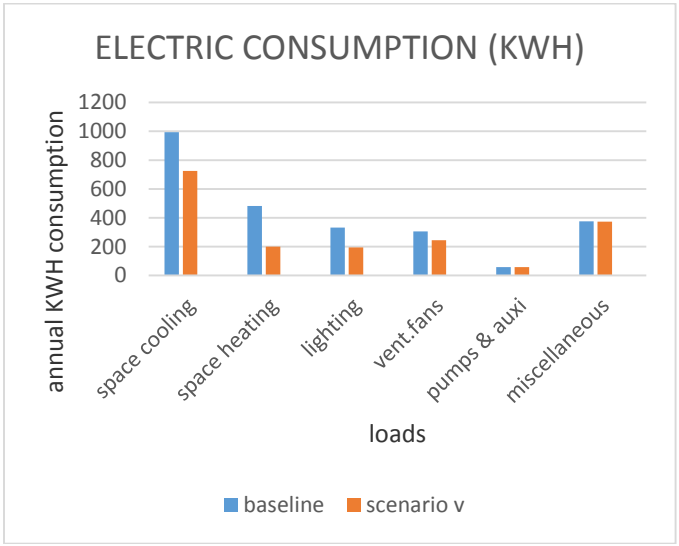

Figure 6 Comparison between Baseline and Scenario-V

F. *Scenario-VI Insulation using 3 inch polystyrene external with EEA*

As the 3-inch polystyrene gives the best results among all other, so in this model external insulation is done for 3 inch of expanded type of polystyrene which gives the best result. The energy consumption is the lowered to 1600 kWh units in this scenario. In this case about 34% energy saving is achieved. The following figure 7 shows the comparison between baseline case and scenario-VI.

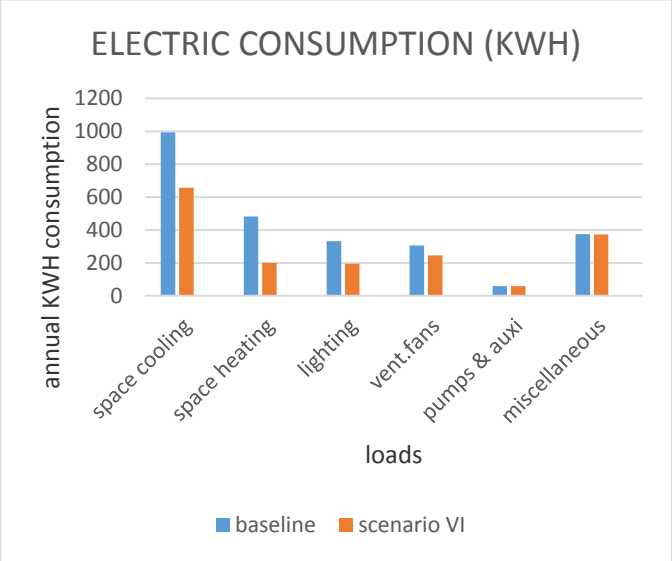

Figure 7 Comparison between Baseline and Scenario-VI

G. Scenario-VII Mixed Insulation with EEA

The total electricity consumption per year has been reduced to 1588 kWh units. This model gives outstanding results but it costs too much. The following figure 8 shows the comparison between baseline case and scenario-VII.

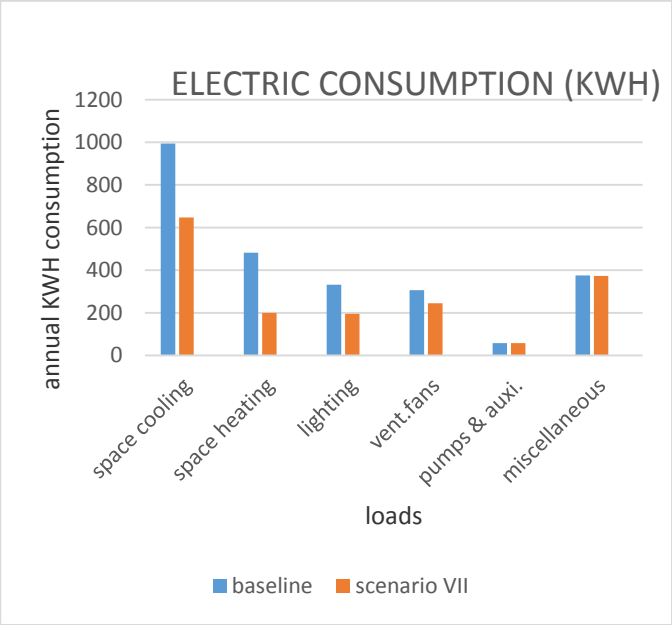

Figure 8 Comparison between Baseline and Scenario-VII

VIII. Comparison

In this section the results of the seven different scenarios with baseline are compared. The comparative graph of all the scenarios with baseline is shown below in figure 11 in the form of line graph. The Y-axis shows the total annual KWH consumption of electricity while X-axis shows various scenarios and the baseline case. A gradual reduction in consumption of electricity can be seen from the graph at each scenario.

IX. Financial Analysis

As the comparative graph showed that scenario seven has the most least electricity consumption. The graph did not provide about the viability and cost of the different scenarios, so detailed financial analysis was conducted to see which scenario is feasible and viable under a 20 years project life. The following table 7 shows the total annual units saved and the payback period of each scenario.

Table 7 Payback period of different Energy Efficient strategies

S.no	Energy Efficient Strategies	Total cost (PKR)	Units Saved (KWH)	Payback Period (years)
1	Polystyrene (3-inch)	109200	583	14
2	Energy Efficient Appliances	100000	577	13
3	Internal (1-inch) polystyrene + EEA	138220	759	14
4	Internal (1.5-inch) polystyrene +EEA	154600	824	14
5	Internal (3-inch) polystyrene + EEA	209200	867	19
6	External (3-inch) polystyrene + EEA	151000	948	12
7	Mixed polystyrene + EEA	360200	960	31

Conclusion

To overcome energy crisis of Pakistan either the generation of electricity needs to be increased or to adopt building design which consumes less amount of energy. First type of solution requires more resources while the second type needs public awareness to design buildings in such a way that it reduces the total consumption of electricity. This research work provided different optimization techniques to lower down the total electricity consumption of a residential building. Seven different scenario analysis is done in this work. Different optimization techniques discussed in this work were, insulation of polystyrene, use of Energy Efficient Appliances and then Energy Efficient Appliances were considered in combination

with different thickness of polystyrene. Polystyrene was taken in different arrangements and in different thickness. Among all the scenarios the sixth scenario i.e. polystyrene (3-inch) external + EEA showed the best results in terms of energy savings as well as it was cost effective. Other models reduced the total consumption up to some extent, the mixed insulation model along with energy efficient appliances lowered down the amount of electricity consumption the most as compared to other models but the drawback in this model is that it costs too much, it is expensive so it is not recommended instead external insulation along with energy efficient appliances i.e. sixth scenario provided the best results, the consumption of electricity reduced to about 37% in this case and also the payback period is less as compared to other scenarios.

REFERENCES

[1] Rashid, Tanzeel-ur. *Energy Modeling and Policy Analysis of Pakistan's Residential Energy System*. Diss. University of Engineering and Technology, Taxila, 2016.

[2] K. kiani, DAWN NEWS, May 2017.

[3] Valasai, Gordhan Das, et al. "Overcoming electricity crisis in Pakistan: A review of sustainable electricity options." *Renewable and Sustainable Energy Reviews* 72 (2017): 734-745.

[4] Balaras, Constantinos A., et al. "Heating energy consumption and resulting environmental impact of European apartment buildings." *Energy and buildings* 37.5 (2005): 429-442.C. Balaras,

[5] Asimakopoulos, D. A., et al. "Modelling the energy demand projection of the building sector in Greece in the 21st century." *Energy and Buildings* 49 (2012): 488-498.

[6] Zhang, Tao, Peer-Olaf Siebers, and Uwe Aickelin. "Modelling electricity consumption in office buildings: An agent based approach." *Energy and Buildings* 43.10 (2011): 2882-2892.