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Low Cost Green Retrofit for Office

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***Abstract*: Building retrofit programme has received significant attention in recent years. This article aims to make a contribution towards low cost green retrofit for office application. The retrofit options suggested in this study includes ventilation system, efficient lighting system, potted plants for better indoor air quality and thermal insulation to walls and roof. The detailed analysis of proposed ventilation system is included in the present study. The comparison between proposed ventilation system with existing air conditioning system is also analyzed. The study demonstrates an efficient way towards achieving low cost green retrofit. The outcomes of this case study will increase the confidence among stakeholders in promoting energy conservation and sustainability.**

***Index Terms*: Retrofit, ventilation, lighting, thermal insulation, indoor air.**

I. INTRODUCTION

Energy conservation has gain lot of importance in today's era, due to exponential increase in energy usage in commercial and residential sector. The energy consumption of existing buildings is far significant than the buildings that will be constructed in the upcoming years. Increasing urbanization and increase in the need for human comfort due to improved life style are the primary reasons for increase in the energy use of buildings [1]. Retrofitting is often preferred by stakeholders to reduce the energy requirements of existing system. The system approach of retrofit is considered to be more advantageous than traditional individual component retrofit approach [2]. The building retrofit programme must include the retrofit scheme, delivery mechanism and payback period [3]. The integration of environmental, sociocultural and economic factors needs to be considered while framing the strategies for retrofitting of office building [4]. Several researchers have explored the feasibility and the benefits of retrofitting residential and commercial buildings [5-14]. Roper and Pope [15] developed a framework for energy retrofit project addressing the common issues and possible solution for a retrofit case. The retrofit approach must also consider the best practices for operation and maintenance of the workplace [16]. Several authors have also used the simulation tool to predict the energy saving potential of retrofit [17, 18]. The Godrej bhavan building in Mumbai, India demonstrates the challenges and the possible solutions for retrofit of an office building [19]. Infosys successfully implemented its deep retrofit program and achieved significant reduction in its energy consumption [20]. Several authors have also performed specific investigations on retrofit measures [21-28]. An exhaustive literature review on building retrofit was made by Ma et al. [29]. The authors also highlighted the need of practical case studies on building retrofit to increase the confidence amongst the stakeholders looking for retrofit programmes.

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II. ANALYSIS

The present study demonstrates a low cost green retrofit for an office use.

A. Existing system

Fig. 1 shows the office layout. The intent of this research is to analyze various retrofitting measures adopted for this office layout. The emphasis is on energy savings and improved occupant comfort.

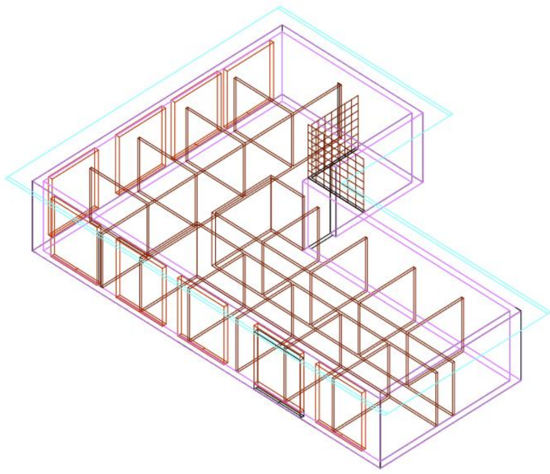


Fig. 1 Existing office layout

The present office layout has 16 cabins installed with 16 unitary split air conditioning units each of capacity 2 Ton of Refrigeration (TR). The key observations of the present layout are summarized below:

1. Except west side, all the other sides of the layout are not directly exposed to solar gain (due to shading effect).

The total occupancy for the given layout is not more than 20. Even then it is observed that the present layout has 16 air conditioning units with each of capacity 2 TR. Thus installation of oversize capacity of 32 TR has resulted in increase in initial cost as well as unnecessary increase in the operational cost.

2. The lighting system comprises of compact fluorescent lamps (CFL).

3. The provision of plants for better indoor air quality (IAQ) is missing.

Fig. 2 shows the existing layout with location of unitary air conditioning unit.

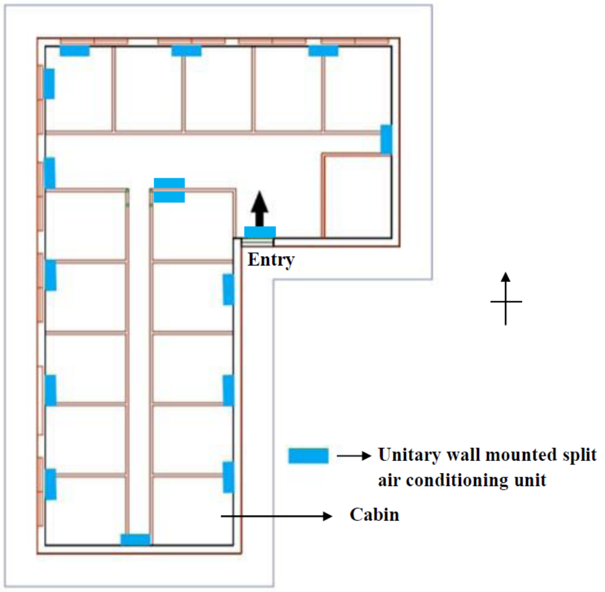


Fig. 2 Layout of existing system with location of air conditioning unit

Poor air circulation is one of the significant drawbacks of unitary split wall mounted air conditioning unit. Therefore in majority of the cases, it is observed that more numbers of air conditioning units are installed than required, to meet the desired air circulation. In the existing layout too, the number of air conditioning units installed are significantly higher than actually needed for human comfort. In addition to this, there is no any dedicated provision of fresh air in such units. Therefore from the view of indoor air quality, these units are not useful for continuous usage.

III. LOW COST GREEN RETROFIT SOLUTION

The retrofit solution for this study includes:

1. Ventilation system instead of air conditioning system
2. Use of LED (light emitting diode) lighting system
3. Thermal insulation to walls and roof
4. Identification of plants for better IAQ.

A. Ventilation system as a retrofit solution to the present situation:

1. Supply and exhaust fan selection

The office layout under consideration does not have significant internal and external heat gain, which indicates that the necessary comfort condition can well be achieved by proper design and installation of ventilation system. The following section describes the selection of ventilation system.

Area of the office space ~ 1816 sq. ft., height of the office space ~ 16 ft.

ACPH = (Fan cfm x 60) / (Room volume in cubic feet)

where ACPH = Air changes per hour, cfm = cubic feet per minute

Selecting ACPH = 8 [30]

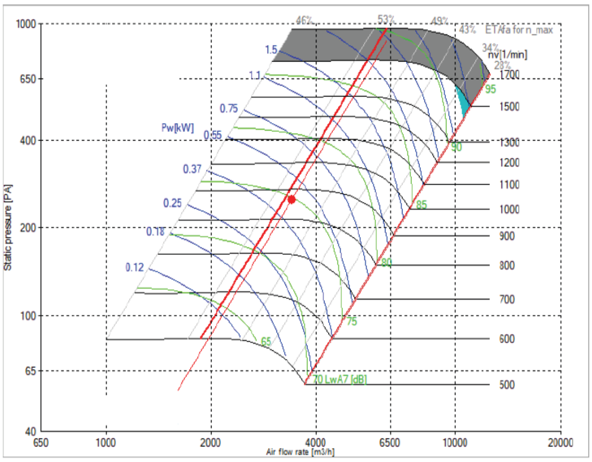
8 = (Fan cfm x 60) / (1816 x 16)

Fan cfm = 3874.13 cfm ~ 4000 cfm ~ 6800 cmh,
where cmh = cubic metre per hour.

Thus for the present case, two supply fans each of capacity 3400 cmh are selected. The supply fan specification and its performance curve are specified in Table 1 and Fig. 3.

Table 1 Technical specifications of supply fan

Parameters	Details
Air flow	3400 cmh
Static pressure	250 Pa
Total pressure	308 Pa
Air density	1.2 kg/m^3
Fan shaft power	0.45 kW
Absorbed power	0.62 kW
Total efficiency	64%
Fan speed	864 rpm
Air velocity	9.79 m/s
Make	Systemair



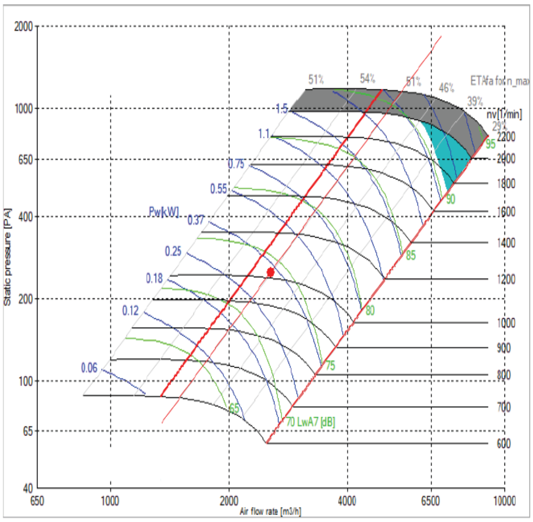
Note- Operating point should not lie within shaded area

Fig. 3 Performance curve of supply fan

Two exhaust fans each of capacity 2550 cmh are selected and the exhaust fan specification as well as performance curves are indicated in Table 2 and Fig. 4.

Table 2 Technical specifications of exhaust fan

Parameters	Details
Air flow	2550 cmh
Static pressure	250 Pa
Total pressure	324 Pa
Air density	1.2 kg/m^3
Fan shaft power	0.35 kW
Absorbed power	0.49 kW
Total efficiency	66 %
Fan speed	1022 rpm
Air velocity	11.08 m/s
Make	Systemair



Note- Operating point should not lie within shaded area

Fig. 4 Performance curve of exhaust fan

Fig. 5 shows the photograph of supply / exhaust fan.

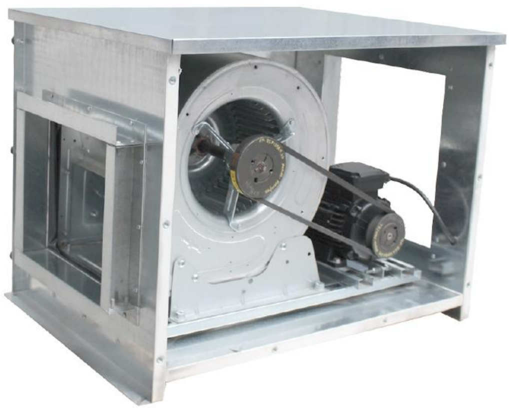


Fig. 5 Photograph of supply / exhaust fan

2. Air outlet selection

Total 18 supply air diffusers are selected, assuming one supply air diffuser in each cabin and two supply diffusers in the common area. Therefore air quantity per diffuser becomes

(6800 / 18) = 377 cmh ~ 400 cmh

The diffuser selection is indicated in Table 3 and Fig. 6.

Table 3 Air outlet selection

Parameters	Details
Air flow	400 cmh
Pressure	31 Pa
Sound	39 dB(A)
Terminal velocity	0.2 m/s
Throw length	4.9 m
Make	Systemair – Konika 200

Fig. 6 Supply air diffuser

The exhaust air is taken directly by exhaust air fan without providing the provision of exhaust air ducting and exhaust air outlets.

The cost of proposed ventilation system is analyzed in Table 4.

Table 4 Cost of proposed ventilation system

Particulars	Specification	Quantity	Unit cost (INR)	Total Cost (INR)
Supply fan	3400 cmh	2	25,000	50,000
Supply air diffuser	400 cmh	18	1500	27,000
Exhaust fan	2550 cmh	2	18,000	36,000
			Total cost	1,13,000

The ducting sizing and layout is not considered in the present study. However, the approximate cost of ducting system is considered while estimating the total cost of retrofit (Table 6).

B. Lighting system:

The lux levels specified for general office spaces is 300 – 500 – 750 [30] and the lighting power density is 9.5 W/m^2 [31].

Considering the above guidelines, we propose to retrofit the existing CFL with LED bulb of Philips make - 7W E 27 6500K (http://www.lighting.philips.com) which provides approximately 720 lumens per bulb.

Considering the lux level of 500 and 720 lumens per bulb, the number of units required works out to be 117 bulbs.

The lighting power density works out to be ~ 4.8 W/m^2 which is significantly lower than the prescribed limit of 9.5 W/m^2 [31].

Assuming the cost of proposed LED bulb to be 150 INR, the total cost of LED lighting works out to be 150 x 117 = 17,550 INR.

C. Thermal insulation:

Insulating the walls and roof will reduce the solar gain into the comfort space and will help in achieving better comfort to the occupants. The wall area in the present layout is ~ 3200 sq. ft. and the roof is ~ 2020 sq. ft. The insulation suggested in this case is extruded polystyrene (XPS).

Assuming the cost of XPS board to be 30 INR per sq. ft., the total cost to insulate the walls and roof works out to 1,56,600 INR.

D. Plants for better IAQ

Use of potted plants for enhancing the IAQ is suggested for the present case. Wolverton et al. [32] has recommended the following plants (Fig. 7) for improving the indoor air quality.

(a) Sansevieria Trifasciata (Snake Plant)

(b) Spathiphyllum (Peace Lily)

(c) Chrysanthemum Morifolium (Florist's Chrysanthemum)

(d) Chlorophytum Comosum (Spider Plant)

(e) Rhapis Excelsa (Lady Palm)

(f) Ficus Benjamina (Weeping Fig)

Fig. 7 Potted plants for better IAQ

Table 5 summarizes the total cost required for implementing the potted plants in present case.

Table 5 Cost of potted plants

Plant	Price per plant (INR)	Quantity	Cost (INR)
Sansevieria Trifasciata (Snake plant)	200	8	1600
Spathiphyllum (Peace Lily)	300	1	300
Chrysanthemum Morifolium (Florist's Chrysanthemum)	300	7	2100
Chlorophytum Comosum (Spider plant)	200	1	200

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Rhapis Excelsa (Lady Palm)	300	1	300
Ficus Benjamina (Weeping Fig)	200	2	400
		Total cost	4900

E. Total cost of retrofit

The retrofit measures adopted in the present situation includes ventilation system, lighting, thermal wall insulation and use of potted plants.
The total cost of retrofit is indicated in Table 6.

Table 6 Total cost of retrofit

Sr. No.	Particulars	Cost (INR)
1	Ventilation System	1,13,000
2	Lighting	17,550
3	Thermal wall insulation	1,56,600
4	Potted plants	4,900
5	Ducting and fan installation charges	69,000
	Total cost	**3,61,050**

The total cost of retrofit comes out to be approximately 4 lakhs INR. This extra cost can be easily recovered through the energy saved in operating the proposed ventilation system.

The comparative analysis between existing system and proposed system is summarized in Table 7.

F. Scenario Analysis

It is also necessary to consider a worst case scenario wherein it might be necessary to operate two unitary split air conditioning units along with proposed ventilation system, to handle peak summer load.
Power consumed to operate the air conditioning units will be 1.2 kW/TR x 4 TR = 4.8 kW ~ 5 kW.
Considering the usage of this 5 kW only during the peak summer (March to May), the annual power consumption works out to be 5 x 66 x 8 = 2640 kWh.
The annual cost of power will be 2640 kWh x 10 INR per kWh = 26400 INR.
Savings in operating cost for ventilation = 576000 – (44400 + 26400) = 505200 INR.
Simple payback period in this case still works out to be less than a year.
The layout of proposed system is shown in Fig. 8.

Table 7 Comparative analysis

Particulars	*UOM	Air Conditioning (Existing) System	Ventilation (Proposed) System
Total capacity required	TR / cmh	32 TR	6800 cmh (supply fan) 5100 cmh (exhaust fan)
Approx. power consumption	kW	38.4 (assuming 1.2 kW/TR)	2.22
Average power consumption (considering 75 % use)	kW	28.8	2.22
Annual consumption	days	250	250
No. of working hours per day	hrs	8	8
Total no. of working hours per year	hrs	2000	2000
Annual power consumption	kWh	57,600	4,440
Assuming, rate per unit consumption	INR per kWh	10	10
Annual cost of power	INR	5,76,000	44,400
Additional cost for retrofit **	INR	-	3,61,050
Savings in operating cost for ventilation system	INR	5,31,600 (576000 - 44400)	-
Simple payback	years	~ 1 year (361050 / 531600)	-

*UOM: unit of measurement
** Referring the total cost obtained from Table 6.

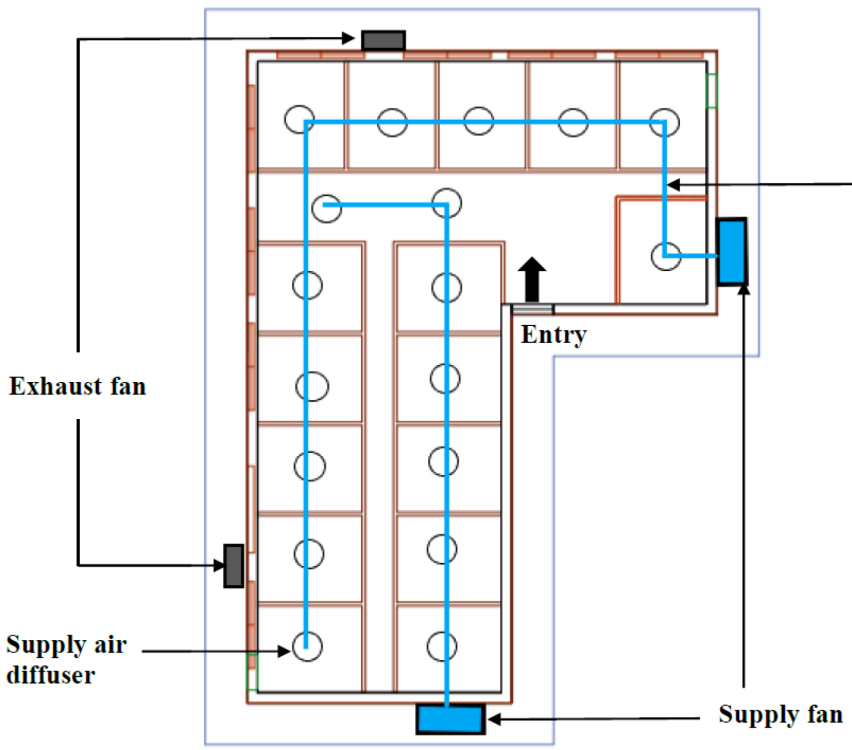

Fig. 8 Layout of proposed ventilation system

IV. CONCLUSIONS

In majority of the cases it has been observed that more numbers of air conditioning units are installed than required, to meet the human comfort requirements. This oversizing of air conditioning system not only increases the initial cost but also has considerable impact on the energy usage. The present research highlights low cost green retrofit options to minimize the energy requirements, without compromising on human comfort. In situations where the occupant space does not have significant internal and external heat gain, the necessary comfort condition can well be achieved by proper design and installation of ventilation system. It is implicit that the ventilation system in comparison with the air conditioning system operates on 100 % fresh filtered air, thereby ensuring better indoor air quality to the occupants. The study also addresses the use of potted plants for enhancing indoor air quality for an office building. The retrofit payback period in the present situation works out to be less than a year demonstrating a promising alternative. A detailed technical analysis is presented to provide a better insight to the stakeholders aiming for retrofitting their existing system for energy conservation.

REFERENCES

1. The Energy and Resources Institute. (2013). *Roadmap for Incorporating Energy Efficiency Retrofits in Existing Buildings*. New Delhi, India.
2. McWilliams, J. A., & Walker, I. S. (2004). *A systems approach to retrofitting residential HVAC systems* (No. LBNL-54696). Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States).
3. Feng Liu. (2014). *Improving Energy Efficiency in Buildings*. Energy Sector Management Assistance Program. Washington, USA.
4. Rey, E. (2004). Office building retrofitting strategies: multicriteria approach of an architectural and technical issue. *Energy and Buildings*, *36*(4), 367-372.
5. Al-Ragom, F. (2003). Retrofitting residential buildings in hot and arid climates. *Energy Conversion and Management*, *44*(14), 2309-2319.
6. Cai, X., Li, H., Feng, G., Yu, S., & Zhao, Y. (2016). HVAC system green retrofit survey and analysis of public institutions building in cold region. *Procedia Engineering*, *146*, 218-223.
7. Kumar, A., Chani, P. S., & Deoliya, R. (2014). Green retrofit potential in existing research laboratories and demonstration of energy efficient and sustainable technologies: case study. *Int. J. Sci. Eng. Technol. Res*, *3*(3), 400-405.
8. El-Darwish, I., & Gomaa, M. (2017). Retrofitting strategy for building envelopes to achieve energy efficiency. *Alexandria Engineering Journal*, *56*(4), 579-589.
9. Becchio, C., Corgnati, S. P., Vio, M., Crespi, G., Prendin, L., & Magagnini, M. (2017). HVAC solutions for energy retrofitted hotel in Mediterranean area. *Energy Procedia*, *133*, 145-157.
10. Radwan, A. F., Hanafy, A. A., Elhelw, M., & El-Sayed, A. E. H. A. (2016). Retrofitting of existing buildings to achieve better energy-efficiency in commercial building case study: Hospital in Egypt. *Alexandria engineering journal*, *55*(4), 3061-3071.
11. Khairi, M., Jaapar, A., & Yahya, Z. (2017, December). The application, benefits and challenges of retrofitting the existing buildings. In *IOP Conference Series: Materials Science and Engineering* (Vol. 271, No. 1, p. 012030). IOP Publishing Ltd..
12. Chidiac, S. E., Catania, E. J. C., Morofsky, E., & Foo, S. (2011). A screening methodology for implementing cost effective energy retrofit measures in Canadian office buildings. *Energy and Buildings*, *43*(2-3), 614-620.
13. Cohen, S., Goldman, C., & Harris, J. (1991). Energy savings and economics of retrofitting single-family buildings. *Energy and Buildings*, *17*(4), 297-311.
14. de Berardinis, P., Rotilio, M., & Capannolo, L. (2017). Energy and Sustainable Strategies in the renovation of existing buildings: An Italian Case Study. *Sustainability*, *9*(8), 1472.
15. O. Roper, K., & Pope, B. (2014). Creating a framework for the successful implementation of energy retrofit projects. *Journal of Facilities Management*, *12*(1), 38-55.
16. Putnam, C., & Price, S. (2005). High-performance facilities engineering: preparing the team for the sustainable workplace. *Journal of Facilities Management*, *3*(2), 161-172.

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DOI: 10.35940/ijrte.B2899.078219
Journal Website: www.ijrte.org

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17. Huang, Y., Niu, J. L., & Chung, T. M. (2013). Study on performance of energy-efficient retrofitting measures on commercial building external walls in cooling-dominant cities. *Applied energy*, *103*, 97-108.
18. Chow, D. H. C., Li, Z., & Darkwa, J. (2013). The effectiveness of retrofitting existing public buildings in face of future climate change in the hot summer cold winter region of China. *Energy and Buildings*, *57*, 176-186.
19. The Natural Resources Defense Council (NRDC) and Administrative Staff College of India (ASCI). (2013). *Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai*.
20. Srinivas, S.N., B. Gadde, S. Seth & V. Dhage (2015). *Implementing Energy Efficiency in Buildings*. United Nations Development Programme, 161. New Delhi, India.
21. Sartori, T., & Calmon, J. L. (2019). Analysis of the impacts of retrofit actions on the life cycle energy consumption of typical neighbourhood dwellings. *Journal of Building Engineering*, *21*, 158-172.
22. Borri, A., Corradi, M., Sisti, R., Buratti, C., Belloni, E., & Moretti, E. (2016). Masonry wall panels retrofitted with thermal-insulating GFRP-reinforced jacketing. *Materials and Structures*, *49*(10), 3957-3968.
23. Raju, V.V.S.S., G. Sastry, M. Kumaraswamy & N. Sagar. (2012). HVAC Retrofit Saves Energy for Infosys. *Air Conditioning and Refrigeration Journal*, 64 – 68.
24. Abdullah, A. (2016). Sustainable and Energy Efficient Commercial Retrofit: Case Study of Perkins+ Will Atlanta Office. *Perkins+ Will Research Journal*, *8*(1), 48-66.
25. Belleri, A., & Avantaggiato, M. (2016). Ventilative cooling in shopping centers' retrofit. *RREHVA J*, 21-5.
26. Dall'O, G., Galante, A., & Pasetti, G. (2012). A methodology for evaluating the potential energy savings of retrofitting residential building stocks.
27. Meek, A., Jayasuriya, N., Horan, E., & Adams, R. (2014). Environmental benefits of retrofitting green roofs to a city block. *Journal of Hydrologic Engineering*, *20*(4), 05014020.
28. Triantis, E. (2005, May). Environmental strategies in retrofitting of educational buildings–The inte-grated approach. In *International Conference" Passive and Low Energy Cooling for the Built Environment", May 2005, Santorini, Greece*.
29. Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and buildings*, *55*, 889-902.
30. Bureau of Indian Standards. (2016). *National Building Code of India, Volume 2, Part 8.* New Delhi, India.
31. Bureau of Energy Efficiency. (2017). *Energy Conservation Building Code*. New Delhi, India.
32. Wolverton, B. C., Douglas, W. L., & Bounds, K. (1989). A study of interior landscape plants for indoor air pollution abatement.