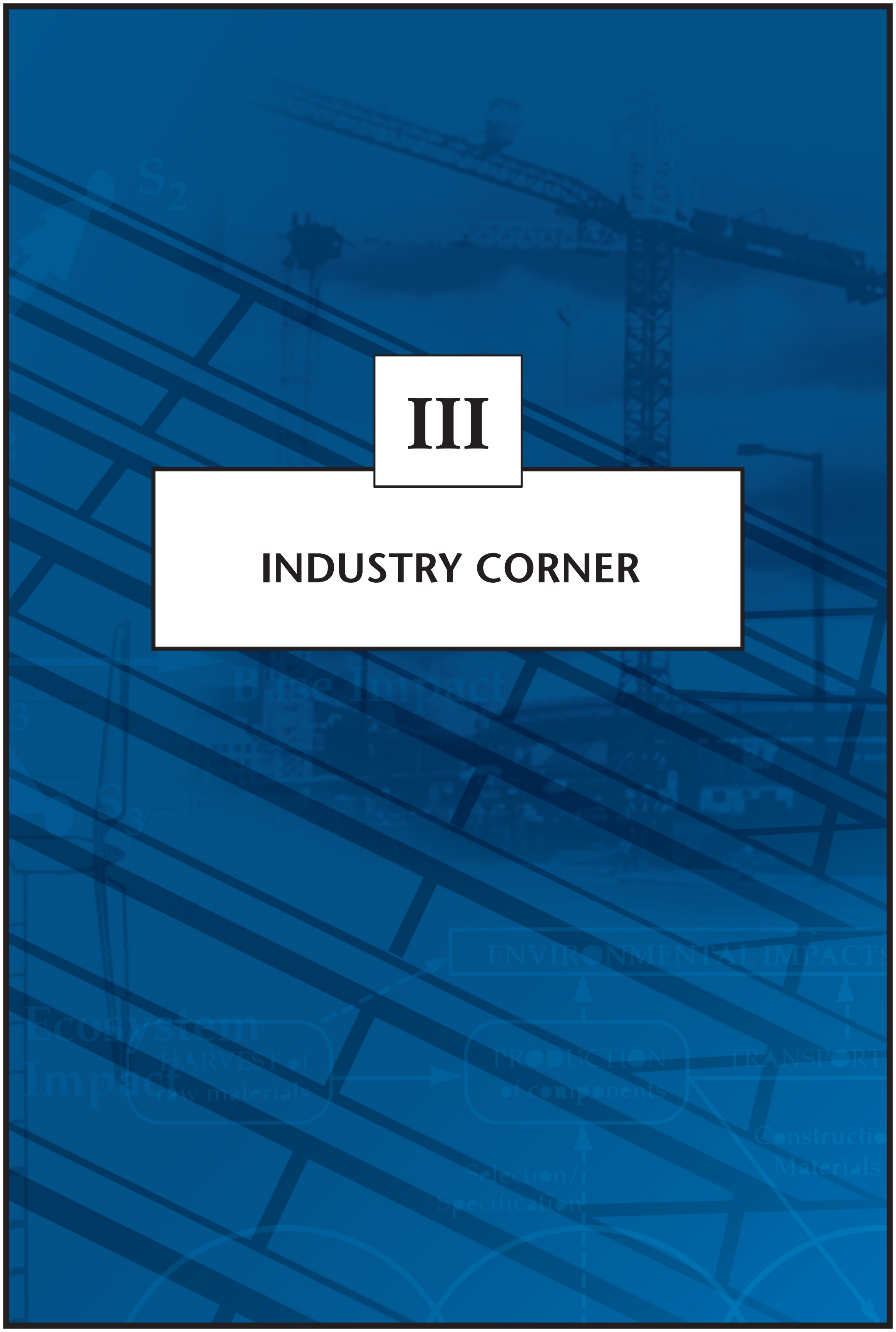


III

INDUSTRY CORNER

MODELING AND FABRICATION OF A KINETIC SOLAR ENERGY-ABSORBING WINDOW AS A GREEN IDEA FOR SUSTAINABLE FUTURE BUILDINGS

Masoud Valinejadshoubi[1], Mannan Ghanizadehgrayli[2], and Sahar Heidari[3]

INTRODUCTION

Renewable versus nonrenewable energy sources and their respective environmental impacts have emerged as preeminent industrial, as well as environmental concerns. Negotiation between policies that promote economic development with those promoting conservationism has yielded promising opportunities for the future. These opportunities engage frameworks focused on economic directives while simultaneously considering the need for environmental directives. Buildings present a unique opportunity for sustainability as they represent the largest proportion of consumed energy, relative to other consumers reliant on the energy grid system. The largest source of energy expenditure in a modern building is through the heating and cooling system which facilitates and maintains a comfortable living temperature. By effectively implementing innovative approaches focused on energy preservation and overall reduction of consumption, it is possible to meet emission reduction goals and mitigate other adverse environmental conditions.

Windows play a vital role in energy consumption and overall maintenance of a comfortable temperature. Understandably, the construction and fabrication of windows are the primary means through which optimized temperatures are achieved. This occurs not only through heat and energy transference but also by providing a protective differential between the inside of the building and the harsh weather conditions of the outdoors. As such, appropriate widow design strategies not only enhance comfort but reduce overall energy consumption. This study seeks to evaluate double-skin windows in order to offer a solution to excessive energy consumption. The windows work by generating a natural ventilation system in summer and then by producing hot air in winter for year-round comfort that is economical. Since current double-skin windows fail to effectively provide ventilation during warm seasons, a kinetic double-skin window was proposed to address this problem and optimize the heating and cooling functions of the building. The results of this research are applicable to modern construction and can be implemented into current design structures.

KEYWORDS

box window facade, kinetic facade, energy efficiency, air heater, natural ventilation

---

[1] . Corresponding author: Young Researcher and Elite Club, Central Tehran Branch, Islamic Azad University, Tehran, Iran. Phone: +989111159858. E-mail address: valinejad.masood@gmail.com.

[2] Young Researcher and Elite Club, Babol Branch, Islamic Azad University, Babol, Iran.

[3] Department of Architecture, Shomal University, Amol, Iran.

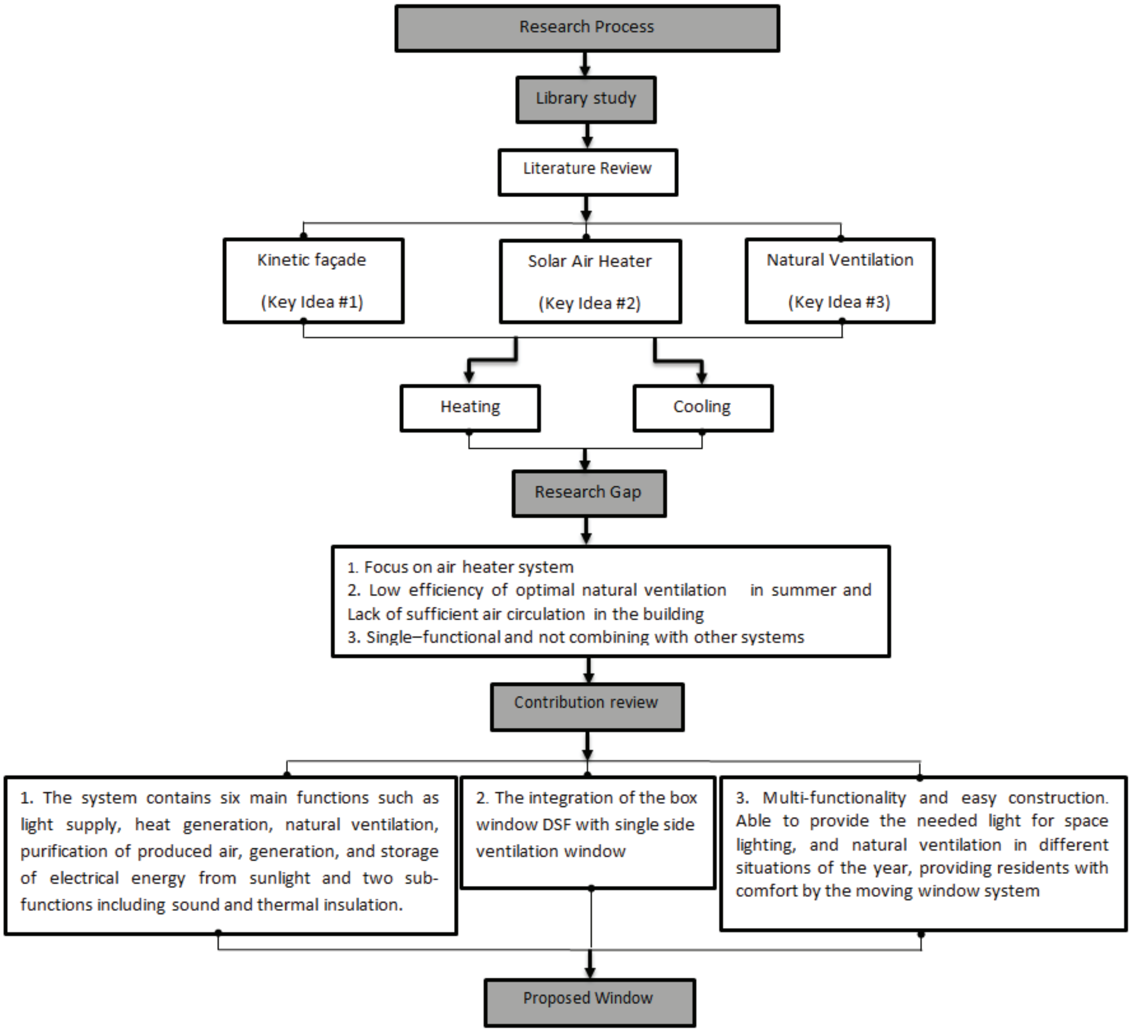
BACKGROUND

The International Energy Agency (IEA) estimates that general electricity consumption within a building is around 42% of the total. This is largely due to people spending on average more than 90% of their time in buildings (Gregory H. Kates 2013). Hence, reduction in the amount of energy consumed through proper and efficient building design is central to sustainability efforts. Such efforts concern policymakers around the world who are charged with balancing economic and broader environmental concerns (Rina Baran et al. 2011). Since the primary source of energy consumption is related to indoor cooling and the heating system, reduction in energy consumption must be centered on appropriate capitalization of natural energy sources, including solar energy and wind.

The strategic architectural and structural design of buildings, as well as the implementation of passive heating, passive cooling, and day-lighting systems, can reduce energy costs upwards of 80% (Antonio Malcangi et al. 2015). Solar energy is an important source of renewable energy with an average insolation level of 1/k 4w/m^2. As such, the 24-hour annual average insolation is estimated to be about 0/k 2W/m^2 (Masoud Valinejad shoubi et al. 2014), effectively illustrating that merely three days of sunlight produces as much energy as can be obtained from all fossil fuel reserves. Solar energy can potentially play a very crucial role for people living in the developed and developing world (Al-Karaghouli 2010). A failure to take advantage of renewable energy sources and avoid environmental hazards caused by fossil fuel consumption invites careful consideration about ways economies might modernize their energy grid systems and implement solar energy to meet day-to-day energy needs. The walls of buildings function as important considerations in energy conservation. As such, one noteworthy adaptation for energy conservation is the mounted solar air heater which functions to reduce around 30% of a building's total energy consumption (Omidreza Saadatian et al. 2013).

Though solar energy has many modern applications, natural ventilation technologies have been historically used for achieving comfortable temperatures (Torwong Chenvidyakarn 2013). Natural airflow also moderates indoor air quality and removes unpleasant smells, as well as other impurities (Marion Russell et al. 2005). During summer, indoor airflow reduced pollution, humidity, and increased coolness. In the last few decades, building designers moved to facilitate airflow in order to remove stale, stagnant air, as well as control thermal temperatures. Improving ventilation and mechanical services allowed construction professionals to effectively design the inner skins of buildings with an open-plan space. The result was an increase in energy consumption (Richard Aynsley 2007) where only 38.9% of the consumed energy was utilized towards ventilation (Zoltán Magyar 2012). Another example can be found in the United States where the average energy consumption is 300 kW h/ m^2, with 79% of the consumed energy being related to lighting and ventilation. The United Kingdom is another example where 72% of aggregate energy reserves depend on these two methods (C. C. Siew et al. 2011). Accordingly, natural ventilation, when properly applied, can greatly lessen the consumption of fossil fuel to service mechanical ventilation (Richard Aynsley 2007). Consequently, an environmental and climate-centered design not only improves efficiency but reduces the cost both financially and ecologically, while simultaneously preserving valuable natural resources (Nedhal Ahmed 2011). The research presented in this paper suggests a novel window design to help resolve the problems of double skin facades (DSF) and problematic fossil fuel consumption to run mechanical systems involved with heating and cooling. The suggested window is a kinetic type that is responsive in all conditions and seasons.

FIGURE 1. Research process.



The building facade is an important element of the building, which has the greatest contact with the outside environment. Unsuitable designs of building façade that fail to consider local climate variations can adversely impact overall thermal function. As a result, achieving an optimal comfort zone necessitates the use of artificial systems (Nedhal Ahmed 2011). In recent years, research has explored various options for meeting the cooling and heating needs of building interiors. These considerations have yielded many innovative options, some of which have been implemented by builders. The DSF development has been instrumental in energy-saving efforts. The DSF meets a variety of performance features based on user requirements and the given climate. Some of these facades focus on generating hot air through solar energy in cold seasons, while others focus on the generation of natural ventilation in hot seasons. The two types of DSF are introduced and explained below.

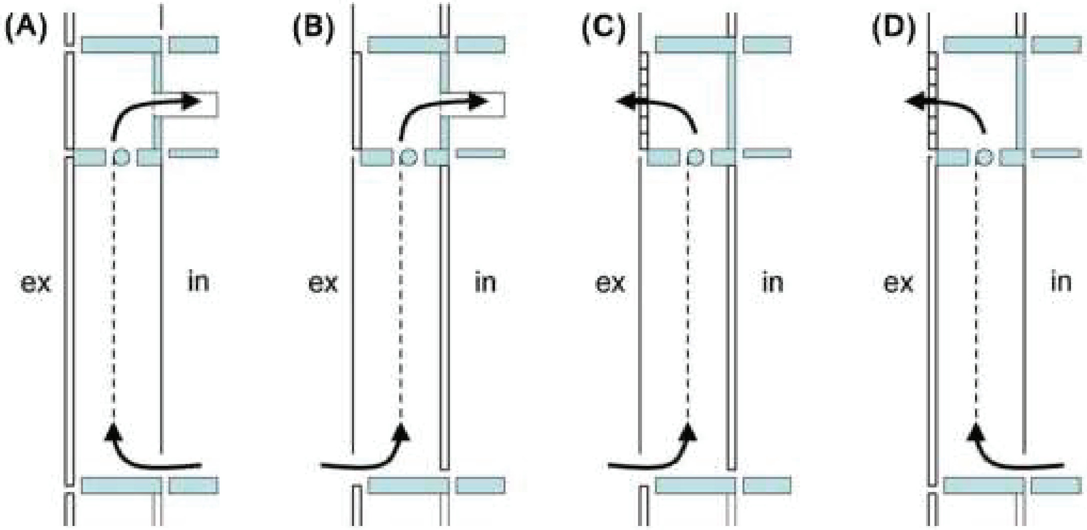
Double-Skin Facade

DSF is a building envelope formed by two layers of different glazing facades, which are accordingly separated by a ventilated air cavity. The cavity of DSF is used to collect or evacuate the solar radiation absorbed in winter and create natural ventilation in summer. As such, it can improve the thermal comfort and the indoor air quality at the same time as saving energy for heating and cooling (Juan Zhou 2010) (Korbinian et al. 2013). A DSF's effectiveness will be contingent upon the following conditions: the type of construction, the type of airflow in the cavity, the origin and destination of airflow of the cavity, the tightness of both skins, and the materials utilized (Frédéric Kuznik rt al. 2011). The degree of temperature and quality of air ventilation are dependent upon the size of the cavity. Experiments by Balocco and Colombari (Mostafa Ahmed et al. 2016) confirm that decreasing the width of the cavity increases the risk of the facade overheating. The first two groups of DSFs are the double skin façades with a large cavity width (0.5m – 1m), and then those that have a smaller air channel (0.10m – 0.3m). According to the different ventilation modes and airflow paths, the working modes for DSF can be classified by four different types. As shown in Figure 2, four configurations are possible by varying the inlet and outlet air (A: indoor air-indoor air, B: outdoor air-outdoor air, C: outdoor air-indoor air, D: indoor air-outdoor air) all of which are dependent on the desired indoor climate condition (Frédéric Kuznik rt al. 2011).

A cavity with different geometrical partitioning is presented in the following forms: Multi-story DSF or curtain wall; Corridor façade; Box window façade; Shaft box type; Facade with horizontal and vertical ventilation (Débora Faggembauu 2006).

A key issue of DSFs is to avoid overheating, especially in summer (Frédéric Kuznik rt al. 2011). The thermal buoyancy-based natural DSF ventilation is produced by the temperature difference between the exterior and interior cavity (separated by the shading devices), which is increased by asymmetric solar radiation and transmittance through the facades (Gratia et al.

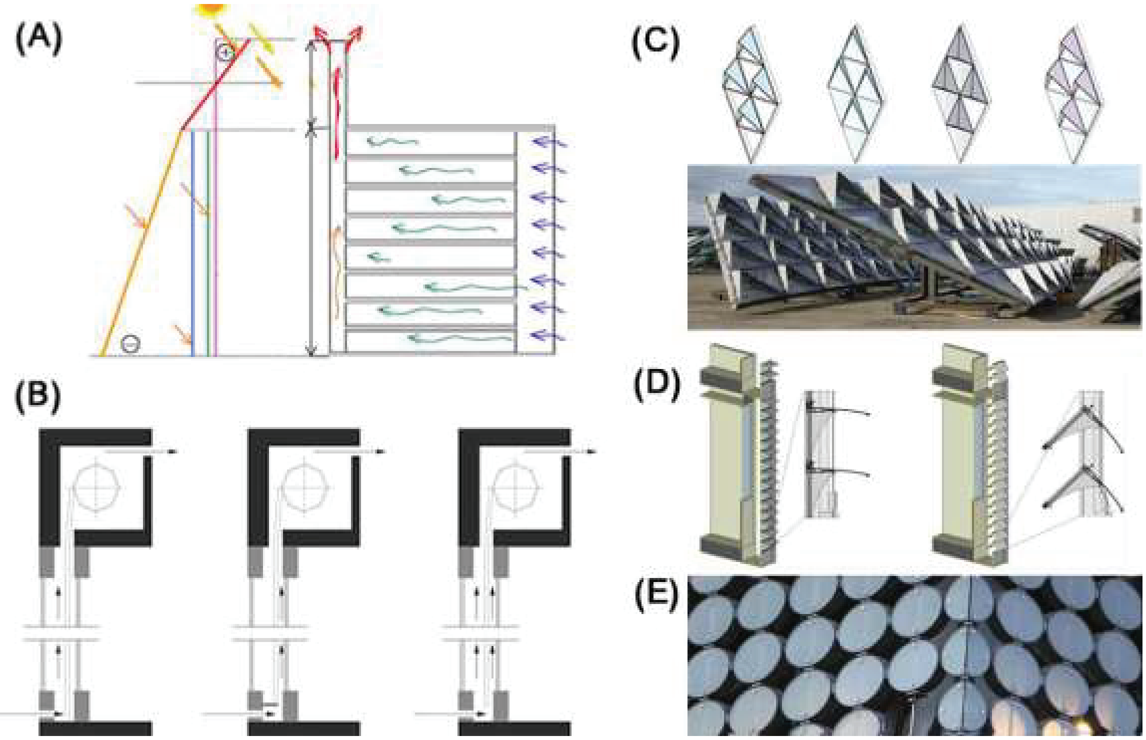
FIGURE 2. Schematic representation of the working modes for double-skin façade (Juan Zhou et al. 2010).



2007), (Sabrina Barbosa et al. 2014). The forced mode means mechanical ventilation of the cavity and the mixed mode is both natural and forced ventilation (Juan Zhou et al. 2010).

The DSF internal airflow is induced through solar radiation and wind flowing around the building. Furthermore, the inner and outer skin of DSF is heated through solar radiation and results in the increase of temperature inside the cavity. Air distribution then reduces the inner pressure of the cavity and is transferred to adjacent spaces (Geum-Hee Kim et al. 2017). In short, by reducing the pressure and velocity of air in the cavity, temperature increases and consequently thermal consumption is decreased (Harris Poirazis 2006). Due to the stack effect, almost 25% of the heat can be removed by natural air circulation. In the last couple years, many suggestions have been offered by researchers to improve the DSF. One suggested DSF, due to the climate of the region, only the heating process was considered. Battle McCarthy (Mostafa Ahmed et al. 2016) reported that the cold climate of the UK, where only heating is necessary, DSF reduced CO_2 by 50% and resulted in an energy savings of 65% relative to a single skin façade. According the model proposed by Wenting Dinga et al. (Wenting Dinga 2005), a thermal tank called solar chimney was installed on the top of the atrium to improve the stack effect (see Figure 3. A) besides panel heaters to increase the temperature of DSF by absorbing sunlight. In considering the design of double windows, Jorge S. Carlos et al. (Jorge S 2010) approved the efficiency of this window system for new and old buildings. They further indicated that the system was able to provide preheated ventilation as well as recover heat lost inside the house and heat transfer from the sun. In this model, the gap is ventilated using a shutter inside the air-gap of the window (see Figure 3. B). This movable shutter can be closed

FIGURE 3. Case study.



at night in three ways, including through the outer gap, through the inner gap, and through both inner and outer gap.

Natural Ventilation through Double Skin Window

Windows are one of the most important components of the building envelope from which several high-level performance requirements are expected (Fatih Yazicioglu 2013) and play an integral role in energy conservation (Cheng Tian et al. 2010). The key concern for designing sustainable windows is the implementation of efficient design strategies with the necessary materials needed for optimal indoor conditioning. Effective planning and execution in the window design process will permit suitable thermal conditioning (Cheng Tian et al. 2010). As air ventilation is a central function of window related temperature control, it follows that airtight windows necessitate a controllable opening that permits airflow (Roger Curtis 2008). Hence, the creation of appropriate windows in the façade of the building is necessary for reducing requirements of ventilation. In order to select the best design, the designer should give careful consideration to the effect of wind, wind direction, and the skin of the building (S.M.Jafarian et al. 2001). Additionally, it should be considered that the relative success rate of natural ventilation in a building depends on the number of openings, doors, and other design mechanisms installed on windows or façades (Heiselberg P 2002).

In order to enter and evacuate the air of the building, the openings of double skin windows play an important role in the creation of positive and negative pressure differentials (Heiselberg P 2002). However, inlet airflow distribution depends on wind speed, direction, shape and size of the building, and most importantly, the size and location of building openings. In a building that has an opening size less than 1.6 of the total area of the façade, the inlet airflow is ultimately unaffected by the openings (Yi Jiang Qingyan Chen 2002). In double skin windows, the single-sided natural ventilation occurs on one side of the wall. As a result, air inflow and outflow are carried throughout one side of the building. For these windows, the air outflow is inefficient; various methods are designed to produce positive and negative pressure differentials. In a building with openings in the wall with the same wind pressure (positive or negative) no significant ventilation occurs, unless the wind pressure is affected by the construction of vertical blades in suitable places and causes deviation of the air path.

Geum-Hee Kim et al. (Geum-Hee Kim 2017) studied the ventilation and cooling performance of DSF during the summer by considering wind characteristics, solar radiation, and heat transfer to facilitate proper ventilation cavities were added to the façade (see Figure 3. C). The ventilation rate of cavities was increased based on the applied speed and pressure of wind over the height of the building. Consequently, when wind flow occurred in front of the building, the air infiltration rate in the cavities was higher than in other directions. It followed that the ventilation rate was decreased by an average of 47.6%. G. Baldinelli (G. Baldinelli 2009) evaluated the double skin façade with two glazed layers and a shading system (see Figure 3. D). During hot seasons, in order to prevent overheating, the outer layer was opened and air escaped from the gap. An inclined shading system prevented penetration of sunlight.

Natural ventilation is possible in all weather conditions through the use of these special windows. Heated air that is located between two glazed skins is transferred inside by the fan. Accordingly, 60 kWh/m^2 energy is saved. In other research, RMIT design Hub with Sean Gosel (see Figure 3. E), implemented a pattern in the façade, which resulted in a cooling of the indoor air and ultimately energy savings. A more favorable temperature was achieved through replacement of air. Perimeter air intakes and fine mist sprinklers incorporated into the double glazed inner skin provided passive cooling to the under floor air distribution (UFAD) system. The used water in this 'Coolgardie safe' system is harvested from the roof.

The most notable challenge of the double skin façade is to create optimized natural ventilation and in this case study, the primary focus is on the air heater system. Today, double skin façades ventilate air as solar chimney's do through temperature differentials of heated air between the double skin and indoor air. The disadvantages of this method include low efficiency in ventilation, lack of sufficient air circulation in the building, and the need for an additional window to guide fresh air into the building. Still, single-sided ventilation is among the most popular of window styles as there are many different rooms on each floor of the building with the opening being centrally located on only one side of the wall. In modern cities, one-sided double skin windows are used as a solution for optimized ventilation. Moreover, disadvantages of the one-sided window are noteworthy and include the following: failure to define the outlet path for air, the absence of sufficient positive and negative pressures for air inflow and outflow, and a depth of air infiltration that is only about 2.5 times that of the roof height. Considering these disadvantages, use of single side ventilation openings is not recommended (Zoltán Magyar 2012). However, it remains true that resolution of these problems and an optimized design makes it possible to reduce the need for cooling equipment by 30% (E. Gratia et al 2004).

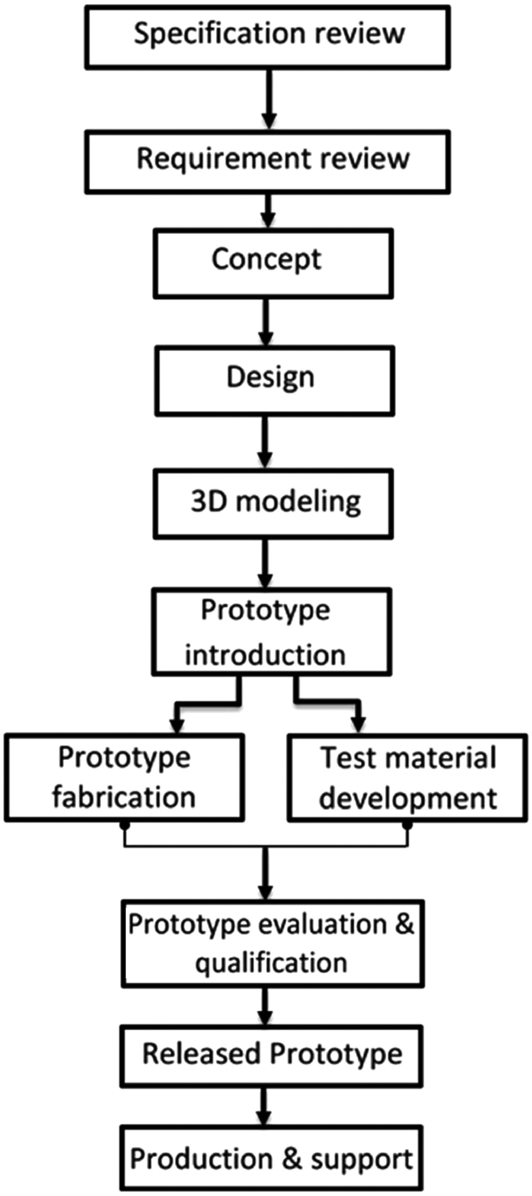
Although energy saving and creation of a better environment for inhabitants of the building is a central focus of research, less attention has been focused on providing ideas for a new product to improve ventilation performance. One of the proposed solutions is the integration of the box window DSF with a single side ventilation window, which results in a movable double skin window. Accordingly, in the following section, a new window is suggested to solve most of the mentioned problems. This system can be installed on older buildings with antiquated design structures. Furthermore, it can be utilized in a variety of different sizes.

PROPOSED SYSTEM

The present study aims to build a window system that is capable of sustaining comfortable temperatures in a variety of different weather conditions. The most significant challenge here is to choose an appropriate window design while keeping in mind multi-functionality. As such, the problems and proposed solutions were evaluated using a similar systematic approach. Among a variety of different designs and patterns, the final design was selected as a new and optimized solution. After functional evaluation of the prototype, it was built (see Figure 4). The proposed design is cable of producing heat in winter as well as natural ventilation in summer. Furthermore, it is multifunctional in its dual purpose as a movable awning. The behavioral study conducted illustrated effective performance in a variety of different climatic conditions. This was enhanced by the absorption of solar energy through photovoltaic panels, conversion into heat in the winter, as well as natural ventilation capabilities which ensure year-round energy efficiency of the building.

The suggested window design is not only possible as a fixture in the construction building, but can also be installed extensively on building windows (see Figure 5). The moving window system, not only has the functions of a normal window but can also provide heat, necessary lighting, and natural ventilation in a variety of conditions. The system contains six main functions, such as light supply, heat generation, natural ventilation, purification of air, generation, and storage of electrical energy from sunlight with sub-functions of sound and thermal insulation.

FIGURE 4. Construction processes.



The proposed system is enhanced by its multi-functionality and ease of construction. The system can convert to an awning by axial rotation in the central point of the system (see Figures 6-8. No. 4). It can function as a solar heater by reverse rotation and window positioning at an appropriate angle to the sun (see Figures 7 and 8). For ease of axial rotation under different conditions, the upper and lower part of the window functions as the folding body (see Figure 6-10. No. 12, 8). Due to the empty space in each position, the flexible covering can be used to insulate these spaces (see Figure 13 No. 16). The fabric acts as a protective insulation and prevents temperature transference between the inside and outside the system. On the outer part of window ceiling, solar cells are utilized (see Figure 14 No. 15). The solar cell generates electrical energy in both positions through exposure to solar radiation.

FIGURE 5. Façade integration of proposed window.

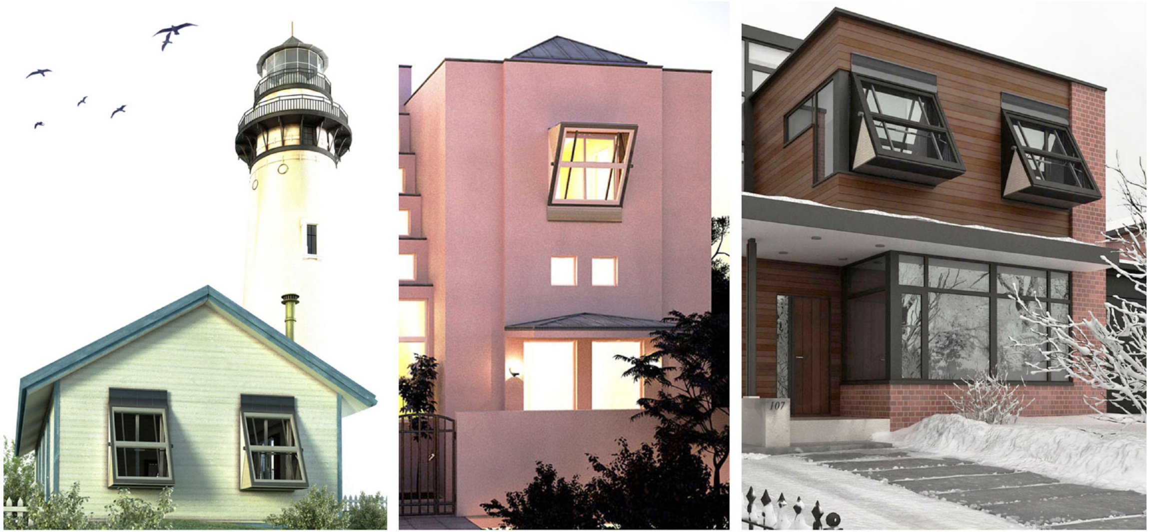
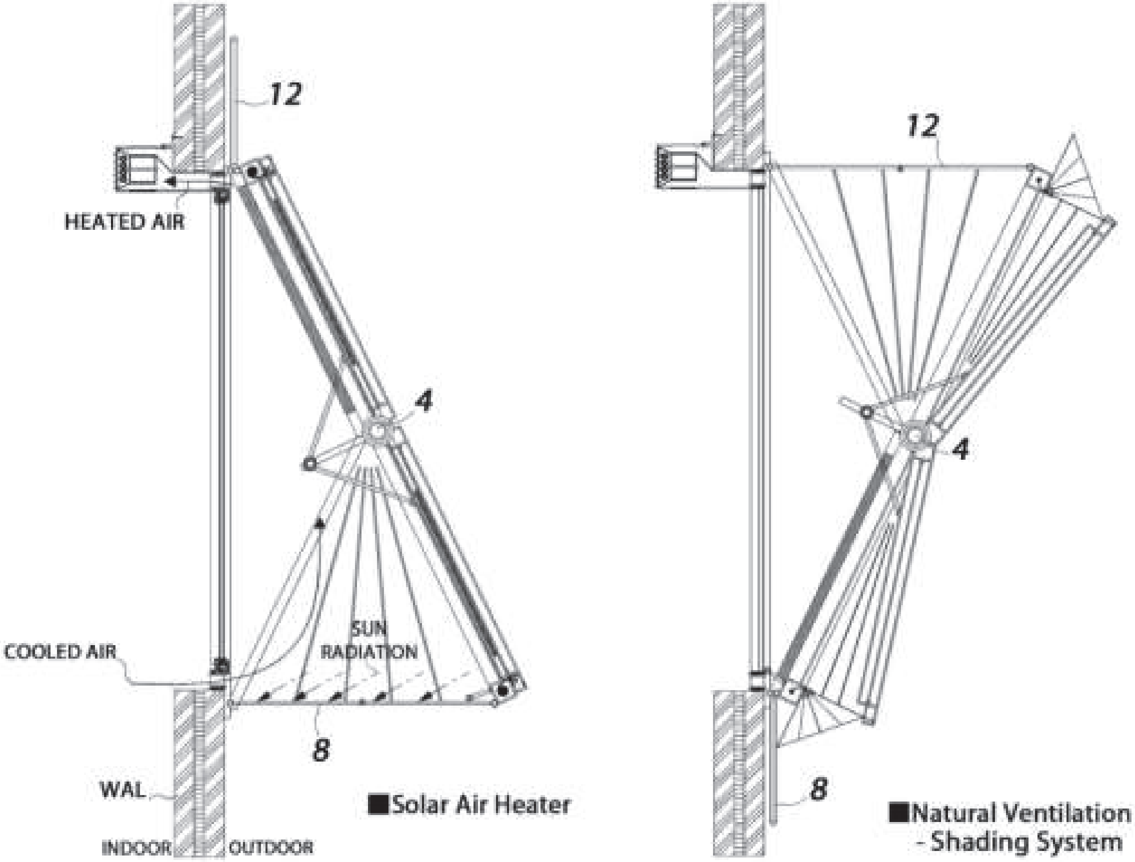

■Solar Air Heater ■Natural Ventilation / Shading ■Solar Air Heater

FIGURE 6. The section of the proposed window in two different positions.



The proposed material is un-plasticized polyvinyl chloride (UPVC), which can heat the inner air by a layer of the absorbent panel placed at its bottom. It should be noted that when the window acts as an awning, the absorbent panel is folded (see Figure 7. No. 8). In order to heat the building in cold weather, a specialized mechanism is required. This is a matte black metal device that absorbs solar radiation and heats the air inside the cavity. The heated air is then transferred into the indoor area of the building through movement of air by fans. Essentially, heat transfer is done through a fluid/air interface. For maximum absorbance of solar radiation, anti-reflective glasses have been installed on the front and back of the proposed window. The elements in the system are possible to heat by using produced electricity through photovoltaic cells that achieve the desired heat. The installed elements are useful for overcast weather or windy days as the necessary heat can still be provided. Airflow is thus effectively heated by elements. In order to accelerate the airflow from system to building, an adjustable fan is installed at the heated air outlet of the system. It should be noted that a filter layer with a Nano-membrane is utilized inside the fan to filter air through the system.

The other function of the system is to produce natural ventilation and artificial shadow. The most effective indoor ventilation occurs when direct sunlight radiation is prevented from entering the building. Through an axial rotation, the upper part of the window, with protrusility, can function as an awning. In order to fully achieve natural ventilation, two openings are necessary. The natural ventilation is performed through flexible fabric blades. The blades help create the positive and negative air pressure in intake and evacuation as a result of the different angles of wind current (see Figure 7).

Manufacturing Process

To perform a functional test of the product and analyze its behaviors, a prototype was constructed. The size of the prototype was considered for a window with dimensions of 1*1m. The prototype has an adjustable feature that allows modification to meet a variety of dimensional needs. In the first stage (see Figure 8. No. 1), a window frame with a thickness of 6 cm was crafted with the product being placed on top, and components being connected to the mainframe.

FIGURE 7. Simulated sample in three positions.

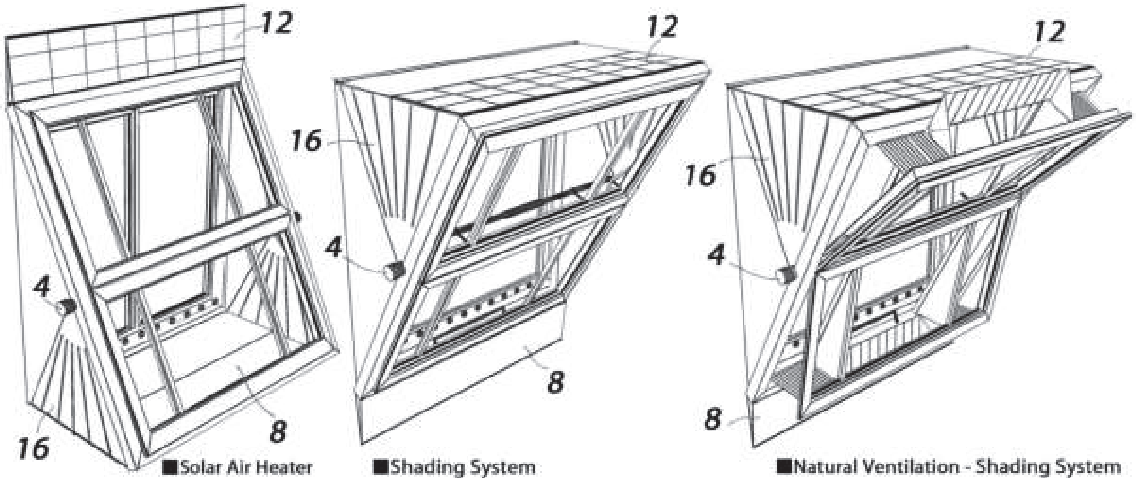
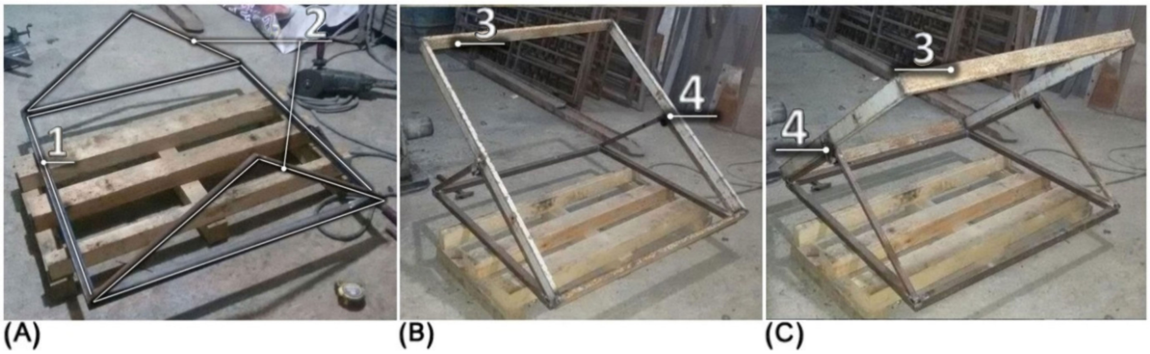


FIGURE 8. (A). Main structure. (B). The movement to the sun. (C). The movement to back the sun.



(A) (B) (C)

In the first step, before connecting the other pieces to the system, two triangular constant pieces (see Figure 8. No. 2) were connected to both sides of the mainframe (see Figure 8. No. 1). These pieces supported the moving frame (see Figures 8. No. 3) to create an axial movement to the sun (air heater) (see Figure 8-B) and back to the sun (create shadow) (see Figure 8-C). The center of the frame was placed on the vertex of the triangular piece (see Figures 8. No. 4), assisting the bearings of the connections. The main structure of the system is responsible for transferring weight load to the facade.

In order to complete the structure of the product, two frames (see Figures 9. No. 7) maintaining the same distance were installed in place of the flexible fabrics (see Figure 13. No.16) as structural blades. On one side, blade frames were connected to the absorbent panel, and on

FIGURE 9. Connection details.

the other, they were connected to the vertex point of the triangular structure (No. 2). At the connection point of the triangle vertex, a bearing was used to allow the frames to open and close during position transitions (see Figure 9. No. 6), as well as for the flexible fabric.

During cold seasons the absorbent panel, installed in the bottom of the frames, plays an important role in absorbing maximum solar energy. The absorbent panel with six metal pieces covers the entire floor of the product for maximum efficiency (see Figure 10. No. 8). These metal pieces are installed between the frames of flexible fabric (see Figure 10. No. 7). The folding absorbent panels are able to open and close through positional alteration. For ease of these actions, a stabilizer chai is used to control the degree to which the absorbent panels open (see Figure 10. No. 10).

In the next step, the folding metal panel (see Figure 11. No. 12) is mounted on top of the system. This panel not only acts as an awning but has the potential to sustain solar panel installation (see Figure 14. No. 15). In both positions, the panel is able to produce electrical energy from the sun. It should be noted that all blade frames (see Figures 9-10. No. 7) cover the upper and bottom of the system (see Figure 13. No. 16). Therefore, the metal absorbent panel through placement in the inner part of blade frame and fabric works to heat the indoor air. Moreover, the awning plate and solar cells are installed on the outer part of the blade frame and the fabric on the top of the system. Accordingly, the solar cells in this position enable the solar cells to have appropriate angling. Also, the fabric functions as a thermal insulation and prevents overheating of the system.

Following completion of the product's structure, the entire surface of the system is painted white. It should be noted that in order to maximize the absorbance of solar radiation in cold seasons all inner surfaces of the product should be colored with a matte black (see Figure 12).

FIGURE 10. Different details of the proposed window.

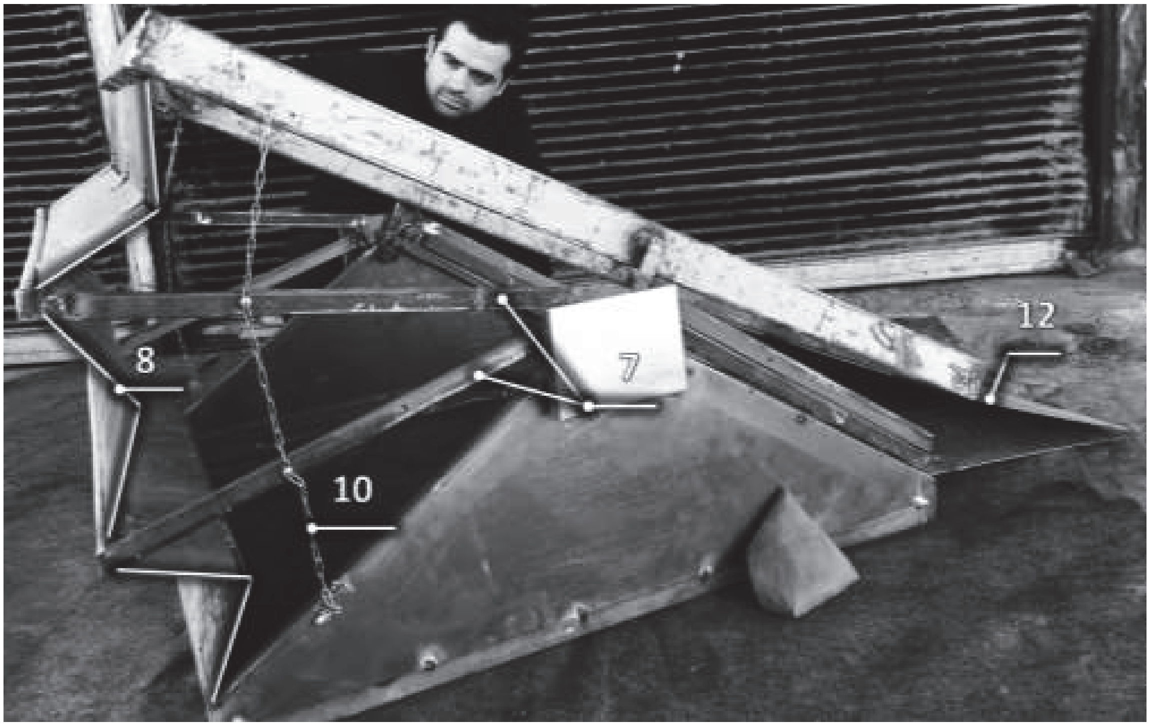


FIGURE 11. The folding panel placed on top of the system and its details.

FIGURE 12. The inner sides of the system was covered with black for absorbing sun radiation.

Next, the window is mounted to the frame of the product structure, moving the structure to the front (see Figure 13. No. 13) and accordingly fixed in the back (see Figure 13. No. 14).

Individually, each of these windows has capable of swift opening and closing for ease of ventilation and temperature control. Before installation of the window, multiple apertures with the same distances are created in the upper and bottom of the UPVC frame by a drill. This

FIGURE 13. The window of the genus UPVC.

allows the flow of heated air into the room during the cold season and inflow of cold air into the product (see Figure 14). Ultimately, flexible fabrics were installed on the desired frames (see Figure 11. No. 7) and solar cells were accordingly mounted upon upper layers (see Figure 14. No. 15).

FIGURE 14. Three positions of the proposed window.

1 Air Heater
2 Shader
3 Natural Ventilation

CONCLUSION

This study aimed to build a movable double skin window system to meet the needs of inhabitants, and the proposed window system could be altered to fit optimized climatic and environmental conditions. To date, several models have been proposed that have only addressed the issue of air heating, as well as the amount of received light and natural ventilation. As of yet, users have not paid much attention to outside views. The proposed system aims to resolve the blatant disadvantages of other models. Through a review of the relevant research literature, a multi-functional and efficient system was constructed. The proposed system not only increases the temperature of the indoor air through protrusility of the window, ceiling, and absorbent panel in winter; it also acts as an awning in the hot, warm summer months. The system is an optimal approach that assists in achieving temperate comfort in modern buildings relative to the more traditional windows.

REFERENCES

1. Zoltán Magyar. Educational Package Ventilation, Lecture 1: Typical ventilation design concepts and strategies. Department of Building Energetics and Building Service Engineering. Intelligent Energy Europe (IDES-EDU). 2012. pp. 5–12.
2. Rina Baran, Codrina Purcaru And Irina Bliuc. Natural Ventilation And Indoor Air Quality In Education Buildings. Buletinul Institutului Politehnic Din Iaşi. 2011. pp. 145–146.
3. Nedhal Ahmed M.Al-Tamimi. The Effects of Orientation, Ventilation, and Varied WWR on the Thermal Performance of Residential Rooms in the Tropics. Journal of sustainable Development/ Vil.4/ No.2/ April 2011/ 142.
4. Fatih Yazicioglu. A comparative analysis of the energy performance of traditional wooden shutters and contemporary aluminium roller shutters in Istanbul, a case study. The Mediterranean Green Energy Forum 2013. MGEF-13/ pp. 483.
5. Cheng Tian, Tingyao Chen, Hongxing Yang and Tse-ming Chung (2010). A generalized window energy rating system for typical office buildings. Solar Energy, 84(7), 1232–1243.
6. Roger Curtis. Ventilation in traditional house, Inform Information For Traditional Building Owners/ Historic Scotland. Published by Technical Conservation Group, October 2008.
7. Heiselberg P. Principles of hybrid ventilation. Annex 35 report. Hybrid ventilation in new and retrofitted buildings. 2002.
8. E. Gratia, I. Bruyere and A. De Herde. How to use natural ventilation to cool narrow office buildings. Building and Environment. 2004, 39(10), 1157–1170.
9. Yi Jiang Qingyan Chen. Effect of fluctuation wind direction on cross natural ventilation in buildings from large eddy simulation. Building and Environment. 2002, 37(4).
10. S.M.Jafarian, S.M.Jaafarian, P.Haseli and M.Taheri. Performance analysis of a passive cooling system using underground channel (Naghb). Energy and Buildings, 42(5), 2001. 559–562.
11. Juan Zhou, Youming Chen. A review on applying ventilated double-skin facade to buildings in hot-summer and cold-winter zone in China. Renewable and Sustainable Energy Reviews. 14 (2010) 1321–1328.
12. Gratia E, Herde AD. Guidelines for improving natural daytime ventilation in an office building with a double-skin facade. Solar Energy 2007; 81:435–48.
13. Débora Faggembauu. Heat transfer and fluid-dynamics in double and single skin facades. Doctoral Thesis. Centre Tecnologic de Transferencia de Calor Departament de Màquines i Motors Tèrmics Universitat Politècnica de Catalunya. 2006.
14. Valinejad shoubi, Masoud, Valinejad shoubi, Mojtaba. Solar Wall System, the Sun-Centered Approach Toward Ecosyste. Journal of Green Building. Volume 8, Number 4. 2014.
15. Korbinian S. Kramer. Solar Rating and Certification Procedures. Solar Heating and Cooling Programme, International Energy Agency. 2013.
16. Al-Karaghouli A and Kazmerski LL (2010) Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software. Solar Energy 84: 710–714.

17. Omidreza Saadatian, Chin Haw Lim, Kamaruzzaman Sopian and Elias Salleh. A state of the art review of solar walls: Concepts and applications. Journal of Building Physics 37(1) 55–79. 2013.
18. Frédéric Kuznik, Ph.D Tiberiu Catalina, Lucie Gauzere, Monika Woloszyn, Jean-Jacques Roux. Numerical Modelling of Combined Heat Transfers in a Double Skin Façade—Full Scale Laboratory Experiment Validation. Applied Thermal Engineering. 2011.
19. Antonio Malcangi, Yi Zhang, Furio Barzon, Defining the energy saving potential of architectural design, Energy Procedia, 2015.
20. Gregory H. Kates. Green Building Costs and Financial Benefits. USA for Massachusetts Technology Collaborative. 2013.
21. C. C. Siew, A.I.Che-Ani and etc. Classification of Natural Ventilation Strategies in Optimizing Energy Consumption in Malaysian Office buildings. The 2nd International Building Control Conference 2011.
22. Torwong Chenvidyakarn. Buoyancy Effect on Natural Ventilation. Cambridge University Press. 2013.
23. Marion Russell, Max Sherman and Armin Rudd. Review of Residential Ventilation Technologies. / Ernest Orlando Lawrence Berkeley National Laboratory. August 2005.
24. Richard Aynsley. Natural Ventilation in Passive Design. Bedp Environment Design Guide. 2007.
25. Sabrina Barbosa, Kenneth Ip, Perspectives of double skin façades for naturally ventilated buildings: A review, Renewable and Sustainable Energy Reviews, 0.1016/j.rser.2014.07.192.
26. G. Baldinelli, Double skin façades for warm climate regions: Analysis of a solution with an integrated movable shading system, Building and Environment 44 (2009) 1107–1118.
27. Geum-Hee Kim, Hyuk-Min Kwon and Jeong-Hoon Yang, Ventilation Rate and Thermal Environment Properties of Double Skin Façade Considering Wind Profile and Direction, JAABE vol.16 no.3 September 2017.
28. Mostafa Ahmed, Ahmed Hamza H. Ali, Prof. Dr. Eng, Journal of Clean Energy Technologies CONTENTS, Volume 4, Number 1, January 2016.
29. Harris Poirazis, Double Skin Facades ;A literature review, A report of IEA SHC Task 34 ECBCS Annex 43, 2006.
30. Jorge S. Carlos, Helena Corvacho, Pedro D. Silva, J.P. Castro-Gomes, Real climate experimental study of two double window systems with preheating of ventilation air, Energy and Buildings 42 (2010) 928–934.
31. Wenting Dinga, Yuji Hasemia, Tokiyoshi Yamadab, Natural ventilation performance of a double-skin fac¸ade with a solar chimney, Energy and Buildings 37 (2005) 411–418.
31. Geum-Hee Kim1, Hyuk-Min Kwon2 and Jeong-Hoon Yang, Ventilation Rate and Thermal Environment Properties of Double Skin Façade Considering Wind Profile and Direction, Journal of Asian Architecture and Building Engineering/September 2017/682.
33. “RMIT Design Hub / Sean Godsell” 22 Feb 2013. ArchDaily. Accessed 23 Dec 2017. <https://www.archdaily.com/335620/rmit-design-hub-sean-godsell/> ISSN 0719-8884.