Use of Eco-Coolers in Indoor Cooling

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Abstract. With the growing global warming and rise in pollution levels across the world in addition to several other factors such as deforestation, urbanization and ozone layer depletion, there has been a continuous increase in global rise in annual average temperature. Eco-cooler is a cheap and eco-friendly device made from non-biodegradable waste which can be used to reduce the indoor temperature of the building thus giving a comfortable living experience. Although a conventional design with symmetrical hole design is adopted in some under-developed countries as a commercial way, no study is being conducted for the improvement in performance of the Eco-cooler. Hence the present study has the main objective of evaluating different factors of dependency of an Eco-cooler, establishing them as a cheap and effective way of reducing indoor temperature and increasing its efficiency.

1. Introduction
Eco-cooler is a cheap and eco-friendly device made from non-biodegradable waste which can be used to reduce the indoor temperature of the building thus giving a comfortable living experience. Although a conventional design with symmetrical hole design is adopted in some underdeveloped countries as a commercial way, no study is being conducted for the improvement in performance of the Eco-cooler. Hence the present study had the main objective of evaluating different factors of dependency of an Eco-cooler, establishing them as a cheap and effective way of reducing indoor temperature and increasing its efficiency. The basic science behind the working is the hot air that enters the bottle through the cut end is compressed gradually at the neck section of the bottle, which in turn turns the air cooler before it enters the room.

1.1. Temperature trends
The present global scenario has seen a drastic change in the world temperature with the average temperature increasing day-by-day. The effects of global warming have taken a significant toll on the daily lives of the people. In the modern world where the climate change is becoming inevitable, the world overall temperature is rising at the rate of 0.8°C/decade.13 of the 15 warmest years overall in the world where in the last 15 years. The last decade was also the warmest. Stats show that in India alone the temperature change trend is very disturbing. Annual mean temperature in India is increasing rapidly. It will breach the 1.5°C marks if it continues to follow the current trend in the next decade. As recorded 2016 was the warmest year of the history. Even during monsoon season, there is an increase of 1°C temp per century. According to the research conducted, it was
established that the outdoor temperature should be around $22^\circ -24^\circ$C for a comfortable living experience. But due to the drastic increase in temperature over the past years, it has become absolute necessary to provide a cheap and effective way of reduction of indoor temperature with sustainability principle in mind.

![Figure-1: Temperature trends in India](image)

### 1.2 Working principle
A survey of the room in which the Eco-cooler needs to be placed is done and the window facing the maximum anticipated air flow is chosen. The ends having larger diameter of the bottles are placed facing out of the window thus permitting maximum air in while not holding further radiation to return within the area. Now, once the air passes through the outer side of the Eco-cooler, the air gets compressed going through the larger diameter section area to the smaller diameter section near the throat.

The compression, due to bottleneck, can increase speed of the air, consecutively decreasing its pressure. The compressed gas undergoes speedy enlargement before long once it leaves the throat of the bottleneck. This speedy enlargement decreases the temp. of the air current and some form of air mass creation takes place that successively attracts the encircling air into the stream.

This Venturi result- the reduction in fluid pressure that results once a fluid flows through a constricted section of a pipe governs the Eco-cooler’s operating. Since the pressure decreases because the speed will increase at the outlet of nozzle in an Eco-cooler, the air commencing of the eco cooler is way cooler than the air getting into (Gay-Lussac's Law).

### 1.3 Objective
The major objectives of the present study are as follow:

a. To analysis the cooling capacity and efficiency of the conventional Eco-cooler.
b. To analysis the wind effect on the cooling capacity of the Eco-cooler.
c. To study the effect of using water as an aid in increasing the efficiency of the Eco-cooler.
d. To analysis the effect of increasing the hole area per surface area on the plywood and adding more plastic bottles on the efficiency of the Eco-cooler.

### 2. Literature review
A deep literature survey was conducted to get a detailed knowledge about the scope, past studies conducted in the field and need for the Eco-cooler. Following are the observations based on cumulative topics.
2.1 Indoor air quality and window positioning
There were specific studies focused on the effectiveness of passive or indirect cooling techniques and its implementation to reduce energy consumption by a building while having the benefit of an improved thermal performance simultaneously. Residential buildings in Dubai were taken for this purpose and a case building was selected. An energy simulation software – IES was used to associate the data obtained with the efficiency of the applied cooling strategies. Solar shading was also used and observed using Sun Cast analysis which was included in the IES software. About 23% reduction in energy consumption was observed with the implementation of the cooling methods. Also, the present scenario for the demand for energy and growing health issues have raised an alarm and hence, natural ventilation is being considered in many areas to be an effective alternative. This mostly depends on the size and orientation of the window openings considering the building is naturally ventilated. Hence, the focus in the research was on single-sided and cross ventilated-buildings and its effects on indoor thermal comfort. Computational Fluid Dynamics was used to study the indoor airflow for a 3D model. Further, it was checked for grid independence and experimental validation was successful on a reduced scale at a wind tunnel and with the network model. Following on the idea that natural ventilation is imperative and open windows are the necessity for having good ventilation. Even then, the knowledge of the efficiency of an open window and its performance remains pretty much unclear. The experiments for two types of windows and their performance in rooms but in an isolated manner were showcased. It showed that airflow inside rooms can be described by the traditional theory as is done for jets. Also, layered flow and semi-empirical flow element models were developed for the estimation of thermal comfort parameters in the occupied region i.e., where human activity is to be present.

2.2 Ventilation effectiveness as indoor room temperature
A study focused on the measurable values that ventilation in domestic buildings can achieve because it is tedious to estimate it using conventional methods and may be costly. The study works on a simple equilibrium-state, heat-balance calculation approach that is backed with monitoring data to model the effectiveness of reducing ventilation rates to the minimum standards for individual homes. In this way, it was easy to differentiate energy consumption and assess how much reduction could occur with this as well as develop better models for further analysis. To understand the temperature variations, it was important to develop better and realistic models that can represent the temperature models and predict heat regulation in an effective manner so that the people can have comfort inside as well energy conservation can be achieved. The continuity, momentum and concentration equations were input in CFD simulations and various models were designed such as the linear ventilation model, low dimensional model, and artificial neural networks to establish the role of ventilation. After the input of the required data, the simulation showed that linear ventilation can be used to predict the indoor environment and heating, ventilation & air conditioning control and bring down air-conditioning costs by about 32%.

2.3 Climate change global warming and greenhouse effect
A research discussing the Greenhouse Gases (GHG) and its effect, the Kyoto Protocol and about the renewable energy sources that are available in today’s world was done. Climate change is directly a consequence of Greenhouse Gas emission. This also told us about the climate change actions taken throughout the USA, Europe, and Asia. It was concluded that GHG Emissions are a problem to the current world’s climate and stated the 4 general measures that can be taken to reduce GHGs so that the market is also not being affected with the measures that will be taken in this process. The burning of fossil fuels emitting CO₂ is the reason for the increase in mean surface temperature and it will increase the temperature by 2-3°C by the middle of next century. Also, the harmful gases like chlorofluoromethanes, nitrous oxide, and aerosols enhance the rate of global warming. The authors insisted to shift towards the use of nuclear energy instead of fossil fuels. As
the CO$_2$ spreads globally, every country must adopt a different way of energy consumption to control the CO$_2$ emission. Global warming is mainly because of deforestation and degraded forests. Restoring degraded forests has a huge potential for averting global climate change.

Due to global warming and increased energy cost, reducing power consumption by computers has become important. Software controls the flow of processing hence indirectly affects the energy consumption and its life cycle energy affects the CO$_2$ emission. Software like Linux 3.2 Kernel and other software of different sizes were taken to analyse the total contribution and the energy consumption associated with their production towards green-house gas emissions. The results have been discussed with the consideration of the sizes of the software ranging from 10 kilobytes to 1 megabyte. They are generic in nature. The result shows that as the software grows, the energy consumed at the production stage will be more than the total lifecycle energy. Linux 3.2 Kernel, the total lifecycle energy of a single copy founded exceeding 51GWh (31 kilotons of CO$_2$ emission)/year.

Research also showed that primary energy demands account for 25% in addition to 11% usage of solid fuels and oils for the purpose of primary home heating in residential sectors of Ireland. Replacing oil and solid fuel usage with air source heat pump (ASHP) technology could offer household cost savings, reductions in emissions, and reduced health impacts. Using this technique, 600 Euros annually can be saved for each household. Not only that, but there can also be a reduction in global CO$_2$ emission by 4.3 million tons per annum. The study also verified the importance of thermal insulation as an effective way of keeping home hot in winter and cool in summer. Ultimately the analysis clearly suggests that ASHPs can play an important role in managing residential emissions.

2.4 Factors responsible for working and construction of eco-cooler
To establish theoretical foundations regarding fluid flow under the venturi effect, a special model called the venturi tube was taken under observation where the effects can be emphasized. A three-dimensional model of the venturi tube was constructed with Solid Edge V20 and analysed using ANSYS CFX for highlighting the fluid flow inside. It was found that this model can provide a solution to determine the fluid flow rate in a hydraulic or pneumatic installation using manometers. 

Venturi shaped roofs can be made for better ventilation and air circulation and research were conducted to validate the same. A specific venturi shaped roof in the University of Putra Malaysia was considered and a case study and CFD simulations were performed. The results showed that the venturi effect could be seen in the specific roof and hence a correct choice of ventilation technique and design has been applied for this case. However, the result can be improved by improving the ratio of contraction and introducing a slight change in the design inspired by Bronsema’s roof design. The Eco-cooler was used for this and this solution can prove effective as the temperature reductions were about 3 degrees Centigrade. Also, the results suggested that the use of a bottle with a 4-inch diameter at the base and 1-inch diameter at the brim will yield better efficiency than other bottles of varying dimensions. Since wind velocity plays an important role in the performance of the Eco-cooler, with an objective of making a detailed wind map of India, long-term data on an hourly basis on wind speed from 70 meteorological centres of India Meteorological Department have been collected and analysed. Using the Gumbel probability paper approach, the extreme value quantities have been derived. A design basis wind speed for each site for a return period of 50 years was evaluated. Following analysis of the collected data after appropriate processing, the site-specific changes in the design wind speeds at the contemporary wind zone map for the design of buildings/structures were highlighted and revisions to the previous map were suggested.

2.5 Gaps identified in literature survey
After going through the literature survey, following gaps were identified:

a. No analysis is done on the cooling capacity and efficiency of the Eco-cooler.

b. Wind effect is not taken into consideration for the cooling capacity of the Eco-cooler.
c. No attempt is made to study the effect of using water as an aid in increasing the efficiency of the Eco-cooler.
d. No analysis is done on the effect of increasing the hole area per surface area on the plywood and adding more plastic bottles on the efficiency of the Eco-cooler.
e. No record of varying material during construction of Eco-cooler to check the effect on the cooling capacity.
f. Possibility of addition of phase transition material as an aid to increase efficiency is neglected.

3. Construction and experimental setup

3.1 Construction of eco-cooler
The guidelines followed for the construction of Eco-cooler for experimentation purposes are as follow:

- a. Measure the dimensions of the window on which Eco-cooler will be mounted.
- b. Take plywood of the same dimension and 6mm thick (transparent or opaque).
- c. Make required inlet diameter cuts on the wood at 10cm c/c distance.
- d. Gather reusable bottles and cut them so that ratio of inner to outer diameter is 1:4.
- e. Silicone Gel is used to adhere the half-cut bottles in positions.
- f. Ensure no further movement occurs by applying aid to the Silicon gel.

Install the Eco-cooler on different windows of the room (based on wind movement direction and requirement)

3.2 Estimation of unit rate of eco-cooler
Considering the window of 3X3 feet for which the Eco-cooler is supposed to be designed.

- Size of Eco-cooler: 4X4 feet (1/2 feet each side for fixing)
- Plywood typical cost being Rs. 80/- square feet (good quality BWP)

BWP Plywood is an acronym for Boiling Waterproof Plywood which is confirming IS 710 specifications and is Marine Grade Exterior Wood.

- Cost of plywood: 80 X 16 = Rs. 1280/-
- Cost of Silicone for one unit (Transparent) = Rs. 200/-

Silicone is the best-known sealant available in the market which bonds almost all types of materials be it wood, metal, or plastic. Silicone is the most used sealant in the civil engineering industry.

- Assuming 50 recycled bottles to be used of suitable diameter of nozzle depending on design.
- Cost of each recycled bottle = Rs. 2/bottle.
- Total cost of recycled bottle = 2X50 = Rs. 100
- Miscellaneous cost for making holes in the plywood = Rs. 200

This involves the cost incurred to drill the holes of required specified and designed diameter by using the drill gun generally which is available with the carpenters and other such workers.

- Total Cost of Eco-cooler for window of size 3X3 = Rs. 1780/-
Cost of Eco-cooler per square feet = Rs. 197.78/- = Rs. 200/-

To cool the same room more easily by using a modern method of reducing the temperature in a room it costs up to Rs. 20000/- which comes up with added on maintenance, electricity bills every month and the other problems that are being caused by the gases and chemicals being emitted by this method.

3.3 Experimental Setup
Following experimental procedure is followed for obtaining observations for different experimental conditions:

a. Mount the Eco-cooler on the window in the direction of the maximum wind flow or opposite to it depending on the experiment.

b. Install 6 temperature sensors (Ambient Weather WS-10-X4 Wireless Indoor/Outdoor 8-Channel Thermo-Hygrometer) (one on each wall, one on roof and one on the floor).

c. In the interval of 15 minutes, note down the temperature change.

d. If the temperature remains constant for 4 consecutive readings, the device has delivered the maximum efficiency.

e. Add a water wall on the diametrically opposite position to the mounted Eco-cooler (if unavailable, use large containers containing water placed near the mounted Eco-cooler).

f. Note the change in temperature in the intervals of 15 minutes.

g. Introduce change in design of the Eco-cooler and note down the effect of the induced change.

4. Observations and results
The following conditions were used to collect observational data and compute them in order to obtain results:

4.1 Assessing the effect of wind on eco-cooler’s performance
Before mounting the Eco-cooler on the actual window, table fan was used to create the wind flow, thus, accumulating the effect of wind velocity on the performance of the Eco-cooler. The observation obtained is recorded as follows:

| Parameters          | 9th March | 10th March | 11th March | 12th March |
|---------------------|-----------|------------|------------|------------|
| Inlet air velocity  | 0.2 m/s   | 0.3 m/s    | 0.4 m/s    | 0.5 m/s    |
| Room temp.          | 24.3° C   | 24.0° C    | 24.8° C    | 24.4° C    |
| Outlet air velocity | 1.1 m/s   | 1.2 m/s    | 1.2 m/s    | 1.3 m/s    |
| Outlet air temperature | 24.3° C | 24.0° C | 24.7° C | 24.2° C |

The data collected shows a directly proportional relationship stating that more the wind velocity, better will be the efficiency and performance of the Eco-cooler. Therefore, it is evident that wind velocity plays an important role in temperature reduction and cooling capacity of an Eco-cooler.
4.2 Eco-cooler (design 1) under normal performance criteria.
The constructed Eco-cooler was mounted on a window with maximum wind flow. Wind velocity at
the start of the experiment was noted and change in room temperature every 15 minutes was noted.

![Figure-2: Design 1 - Square pattern arrangement](image)

**Table-2**: Observation on cooling capacity (wind velocity at start 3.2 m/s)

| Time interval (min) | Initial temp. (°C) | Final temp. (°C) | Reduction in temp.(°C) | Cooling capacity (°C/hr.) |
|--------------------|-------------------|-----------------|------------------------|---------------------------|
| 0-15               | 26.8              | 26.7            | 0.1                    | 0.4                       |
| 15-30              | 26.7              | 26.5            | 0.2                    | 0.8                       |
| 30-45              | 26.5              | 26.2            | 0.3                    | 1.2                       |
| 45-60              | 26.2              | 25.9            | 0.1                    | 0.4                       |
| 60-75              | 25.9              | 25.9            | 0.0                    | 0.0                       |

**Calculations:**
- Overall Reduction in temperature (R) = 26.8 °C - 25.9 °C = 0.9°C
- Cooling Capacity = 0.9 °C ÷ 1.25 hr = 0.72 °C/hr
- Efficiency = (0.9 °C ÷ 26.8 °C) x 100 = 3.36%

4.3 Eco-cooler (design 1) with water aid
The same mounted Eco-cooler is now aided by keeping a large water container which will
theoretically absorb the heat and thermal energy from the entering air thus giving a better cooling
experience. (Wind velocity at the start 2.9 m/s).
Table-3: Observation of cooling capacity

| Time interval (min) | Initial temp. (°C) | Final temp. (°C) | Reduction in temp. (°C) | Cooling capacity (°C/hr.) |
|--------------------|--------------------|------------------|------------------------|--------------------------|
| 0-15               | 27.6               | 27.3             | 0.3                    | 1.2                      |
| 15-30              | 27.3               | 27.1             | 0.2                    | 0.8                      |
| 30-45              | 27.1               | 26.7             | 0.4                    | 1.6                      |
| 45-60              | 26.7               | 26.5             | 0.2                    | 0.8                      |
| 60-75              | 26.5               | 26.3             | 0.2                    | 0.8                      |
| 75-90              | 26.3               | 26.2             | 0.1                    | 0.4                      |

Calculations:
- Overall Reduction in temperature (R) = 27.6 °C – 26.2 °C = 1.4 °C
- Cooling Capacity = 1.4 °C ÷ 1.5 hr = 0.94 °C/hr
- Efficiency = (1.4 °C ÷ 27.6 °C) x 100 = 5.07%

4.4 Eco-cooler (design 2) with water aid
A new Eco-cooler with modified design (Figure) was constructed so that to increase the amount of intake wind coming from the window. Water container was placed near the Eco-cooler mounted window as the same experimental procedure was followed. (Wind velocity at start 3.6 m/s).

Figure-3: Design 2 (A)  
Figure-4: Design 2 (B)
### Table-4: Observation of Cooling Capacity

| Time interval (min) | Initial temp. (°C) | Final temp. (°C) | Reduction in temp. (°C) | Cooling capacity (°C/hr.) |
|---------------------|---------------------|-------------------|-------------------------|---------------------------|
| 0-15                | 25.6                | 25.3              | 0.3                     | 1.2                       |
| 15-30               | 25.3                | 25.0              | 0.2                     | 0.8                       |
| 30-45               | 25.0                | 24.6              | 0.4                     | 1.6                       |
| 45-60               | 24.6                | 24.1              | 0.2                     | 0.8                       |
| 60-75               | 24.1                | 23.9              | 0.2                     | 0.8                       |
| 75-90               | 23.9                | 23.8              | 0.1                     | 0.4                       |
| 90-105              | 23.8                | 23.7              | 0.1                     | 0.4                       |

**Calculations:**
- Overall Reduction in temperature (R) = 25.6 °C − 23.8 °C = 1.9 °C
- Cooling Capacity = 1.9°C ÷ 1.75 hr = 1.09 °C/hr
- Efficiency = (1.9°C ÷ 25.6 °C) x 100 = 7.42%

### 4.5 Result Tabulation

### Table-5: Comparative analysis of Efficiencies

| Design and setup       | Overall Reduction in temperature | Cooling capacity overall | Efficiency |
|------------------------|----------------------------------|--------------------------|------------|
| Eco-cooler-1           | 0.9 °C                           | 0.72 °C/hr.              | 3.36%      |
| Eco-cooler-1 with water aid | 1.4 °C                           | 0.94 °C/hr.              | 5.57%      |
| Eco-cooler-2 with water aid | 1.9 °C                           | 1.09 °C/hr.              | 7.42%      |

It is clear from the results that:
- More Void area/surface area gives better result and cooling capacity.
- Introducing a heat absorbent aids to the performance of the Eco-cooler.
- Wind velocity has a huge effect on the performance of the Eco-cooler, i.e., better wind flow is directly proportional to the performance of Eco-cooler.
5. Conclusions
Following are the conclusions drawn from the present research:

- As the temperature around the globe has started to grow at an unprecedented rate, it has become the need of the hour to look for viable options that can help people everywhere, to help them survive the worst-case scenarios that may come in the future.
- The data that has been shown in this paper has shed a light on how the temperature variations may occur in the next few decades. Therefore, if a concrete solution to this is not developed then most of humanity will eventually have to perish.
- Apart from temperature variations, multiple other phenomena are happening that can have dire consequences upon mankind with each one of them having catastrophic effects later on.
- Multiple cooling strategies are being researched currently but most of them are at the expense of electricity thus, it is uncertain that the solution would apply to masses as the cost of the cooling device will be marginally high.
- Also, it is known that electricity is not omnipresent and because of this, not a lot of things can be used as a solution. Hence, low-cost alternatives although hard to find must be researched upon as they can prove to be a boon to people who may be economically challenged.
- In this paper, the same has been tried to establish with the help of an Eco-cooler. Temperature sensors were used to see the effect of varying parameters on the performance of the Eco-cooler inside a closed environment.
- Benefits of using an Eco-cooler are mentioned in this paper and also how it can impact the environment as well as be in harmony with the cooling capabilities. The cost of a typical Eco-cooler is roughly Rs. 200/- per square feet which is affordable for most of the Indian families.
- The construction procedure and its setup are fairly simple and hence, it can be done with simply without the need for external assistance. Apart from this, the Eco-cooler can be used in conjunction with other home appliances as such the table fan and hence, facilitating the cooling effect.
- It is also observed that a certain pre-requisite mainly, wind flow is one of the most important criteria for the working of the Eco-cooler. Hence, places where the natural wind velocity would be constant and have a higher magnitude, the Eco-cooler would perform better.
- Also, establishing the result on efficiency by the use of external aids such as a water-wall which have proven to improve the performance of the Eco-cooler, up to some extent.
- A step is taken in the direction of providing a solution which is much more economically viable and as the Air Conditioner are being used today its usage adds on to multiple emissions and although the room inside becomes cooler, it is not affordable for everyone, apart from its consequences to the environment.
- This paper aims to understand how these variables can be changed and even provide a solution that has another impact on everyone.
- At last, although the obtained results are not in accordance to the required results and the efficiency is not as much as it was predicted. Further research needs to be done in this field to improve the efficiency of the Eco-cooler and prove to be helpful.
6. Scope for future work

- Eco-coolers have a big future ahead. There are some improvements which were not included in this paper such as using phase transition materials.
- Use of phase-transition elements or heat sink can prove beneficial.
- There is a scope in using different materials for bottles and the support on which bottles are fixed.
- Different shapes of bottles can also be adopted in future to enhance the performance of the Eco-cooler.
- As the supporter or the plywood prevents the view of the outside of the window, different transparent materials can be used to overcome this problem.
- Making the design as two door panel window can be adopted.

References

[1] A F Zobaa & J S McConnach 2006 International response to climate change: an overview IEEE Power Engineering Society General Meeting Pgs 465-473.
[2] Tapan Kumar Rana, Anik Naha Biswas, Debashmita Basu, Biswarup Rana, Debaleena Mukherjee, Paboni Das and Bhaskar Kumar 2017 Impending impact of climate change on present and future generations 8th Annual Industrial Automation and Electrotechnical Engineering Conference. Pgs. 22-27.
[3] Munniyandi Balasubramani, V Dholasi Birundha. Climate change and its impact on India The IUP Journal of Environmental Sciences vol. 6 Pgs 31-46.
[4] Vidadi Samedov, Iskandarova Tunzala Hasan Kizi. Study of deforestation and degraded forests as a main source of biodiversity loss and global warming Conference: Rehabilitation & Restoration of Degraded Forests Pgs. 1-9.
[5] Himangka Kaushik, Mobi Mathew and Jami Hossain 2018 Comparative analysis of greenhouse Gas Emission from different Vehicular fuels 1st IEE International Conference on Power Energy, Environment & Intelligent Control (Greater Noida, Uttar Pradesh, India) Pgs. 702-706.
[6] Safiuddin Md 2001 Global ozone depletion: Cause effects and preventive measure Borneo Science vol. 10 Pgs 73-89.
[7] J W Jones, W F Stoecker. Refrigeration and Air Condition McGraw-Hill Edition.
[8] J X Zhang 2017 Analysis on the effect of venturi tube structural parameters on fluid flow AIP Advances vol 7 Pgs 1-9.
[9] Bhanuprakash Ch, Vinod Mummina and Mahesh Chakravarthi V 2018 Performance evaluation of an eco-cooler analysed by varying the physical and flow parameters IOP Conf. Series: Materials Science and Engineering vol 377 Pgs. 120-124.
[10] Hanan M Taleb 2014 Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings Frontiers of architectural research vol. 3 issue 2 154-165.
[11] D Prakash, P Ravikumar 2019 Analysis of thermal comfort and indoor air flow characteristics for a residential building room under generalized window opening position at the adjacent walls vol 4 issue 1 Pgs. 42-57
[12] Per Heiselberg, Henrikn Dam, Lars C. Sarensen, Peter V Nielsen, Kjeld Svid 2001 Characteristic of airflow from open windows Building and Environment vol. 36 issue 7 Pgs. 859-869.
[13] P Cosar-Jorda, R A Buswell, V A Mitchell 2018 Determining of the role of ventilation in residential energy demand reduction using a heat-balance approach Building and Environment vol. 144 Pgs. 508-518.
[14] Chen Rena, Shi-Jie Cao 2019 Development and application of linear ventilation and temperature models for indoor environmental prediction and HVAC systems control Sustainable Cities & Society vol. 51 01673.
[15] Sook-Ling Chua 2015 Sensor Selection in Smart Home Procedia Computer Science 69 vol 23 Pgs. 43-57.
[16] Alexandra Schiewecka, Erik Uddea, Tunga Salthammer, Lea C Salthammer, Lidia Morawska, Mandana Mazaher, Prashant Kumar 2018 Smart homes and the control of indoor air quality Vol. 94 Pages 705-718.
[17] Shanshan Tonga, Nyuk Hien Wonga, Erna Tana, Steve Kardinal Jusuf 2019 Experimental study on the impact of facade design on indoor environmental quality in tropical residential buildings Building and Environment vol. 166 Pgs. 1-15.
[18] Bruce Spencer, Omar Alfandi 2016 Forecasting Internal temperature in a Home with a Sensor Network vol. 89 Pgs. 1244-1249.
[19] C Monica, S Kalaivani, Gopalakrishna Jayalalitha 2018 Forecasting the annual temperature of India by Using Exponential Smoothing Journal of Advanced Research in Dynamical and Control Systems 06 special issue Pgs. 972-976.
[20] Xu Hong, He Yuan, Sun Xiang, He Jia, Xu Qiongmei 2020 Prediction of thermal energy inside smart homes using IoT and classifier ensemble techniques Computer Communication vol 151 Pgs. 581-589.

[21] William W Kellog, Stephen H Schneider 1978 Global Air Pollution and Climate Change IEEE transaction on Geoscience vol. 16(1) Pgs. 44-50.

[22] Vasily G Moshnyaga 2013 Assessment of Software Lifecycle Energy and its Contribution to greenhouse Gas Emissions IEEE International Conference Cloud and Green Computing vol 3 Pgs. 197-198.

[23] Bimal Bose 2010 Global Warming: Energy, Environmental Pollution, and the Impact of Power Electronics IEEE Industrial Electronics Magazine vol 4(1) Pgs. 6-17.

[24] J Andrew Kelly, Miao Fu, J Peter Clinch 2016 Residential home heating: The potential for air source heat pump technologies as an alternative to solid and liquid fuels vol. 98 Pages 431-442.

[25] Markand Oza, Chandra Kishtawal 2015 Spatio-temporal changes in temperature over India IEEE Current Science vol 109 Pgs. 154-158.

[26] Shouraseni Sen Roy 2019 Spatial patterns of trends in seasonal extreme temperatures in India during 1980–2010 Article in Weather and Climate Extremes vol 24 Pgs. 1-7.

[27] Gulrez Azhar, Shubhayu Saha, Partha Ganguly, Dileep Mavalankar and Jaime Madrigano 2017 Heat Wave Vulnerability Mapping for India Sustainable Environmental and Research Conf. Vol. 14(4) Pgs. 847-852.

[28] Fănel Dorel ȘCHEAUA 2016 Theoretical Approaches Regarding the VENTURI Effect Conference of Hydraulics, Pneumatics, Tribology, Ecology, Sensors, Mechatronics issue 3 Pgs. 69-72.

[29] P Farzan, M Soheilirad, M L Othman, M Hojabri, M M Broujerdian 2013 CFD Analysis of wind blocking vs Venturi effect: A case study in tropical climate IEEE International Conference on Renewable Energy and Sustainable Energy (Karunya University Coimbatore, India) Pgs. 192-195.

[30] Subha Ganguly 2018 Plastic pollution and its adverse effect on Environment and Ecosystem Internation conference on Recent Trends in Arts, Science, Engineering & Technology (dhanalakshmi Shrinavasan Hotel, Perambalur, Tamil Nadu, India) pgs. 15-16.

[31] N Lakshmanan, S Gomathinayagam, P Harikrishna, Arthur Abraham, S Chitra Ganapathi 2009 Basic wind speed map of India with long-term hourly wind data IEEE Current Science vol. 96 Pgs. 911-922.