The trend of hybrid ventilation systems

V Soebiyan

Architecture Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

Vivien.soe@binus.ac.id

Abstract. The topic of green building has increasingly relevance due to its contribution to the satisfaction of environmental needs while sustainable architecture. Global energy demand has been increasing rapidly due to building energy consumption. The largest share of the building energy consumption particularly for Heating, Ventilation and Air Conditioning (HVAC). To reduce this energy consumption, hybrid ventilation (HV) can be applied which combines natural and mechanical systems. This paper discusses the trends of HV publication. In this context, we conducted an analysis of 233 papers related hybrid ventilation from the Scopus database for the 39 years. This paper develops a bibliometric analysis with the aim of assessing the key papers in the field and identifying the most substantive contributions to the literature. The result show, based on the trend, there is an increasing trend in researchers towards hybrid ventilation in buildings.

Keywords: Hybrid ventilation, bibliometric, trends

1. Introduction
The last few decades, global energy demand has been increasing rapidly. The building sector consumes up to 40% of the world's energy use [1]. Buildings represent the largest share of this consumption particularly for Heating, Ventilation and Air Conditioning (HVAC), 47% in US [2] 40-45% in India [3] 40-44% in Lebanon [4]. In warm humid tropics, such as Indonesia air conditioning is the most dominant factor in building energy use, even 84% in government buildings and 60% in other buildings [5]. Mechanical ventilation contributes to the high energy use of buildings.

An approach can be made by combining natural and mechanical ventilation for indoor temperature cooling to achieve thermal comfort with reduced energy consumption. The previous study highlighted these purposes as hybrid ventilation. Hybrid ventilation as a system in which a comfortable room environment uses natural ventilation and mechanical systems, using the different features of this system at different times of the day or season [6][7][8]. In a more general discussion, hybrid ventilation can be defining as ventilation with natural and mechanical ventilation principles which together determine the air flow in the room [9]. Hybrid ventilation combines two ventilation systems that have different design principles and strategies that can even be contradictory. Based on a literature study examining hybrid ventilation in areas with four-season climates, it is shown that it can achieve up to 50% efficiency energy and improve IAQ [10]. Hybrid ventilation were first and widely developed in Europe, with the use of control systems and sensors. This is due to the utilization advanced technology and better energy efficiency building awareness. Building owners for moving towards greener building [11]
This paper aims to provide an overview of the current research related to the hybrid ventilation. This paper describes the trends of hybrid ventilation research through bibliometric analysis study. Bibliometric analysis as known as the use of statistical methods to analyse publications and quantitative examines in bibliographic materials. Bibliometric analysis can show the trends of the certain topic, therefore, it possible to know the past, understand the progress of the times investigations and enhance future research. The information generated is also useful in decision making [12]

2. Method
Bibliometric method was used to trace the relationship between academic journal citations. In this study, bibliometric analysis method is intended to show the trends regarding ventilation hybrid. For this purposes, this study uses the bibliometrix application [13], an R-tool for comprehensive mapping analysis. For visualization, it comes with biblishiny application interface. The bibliometrix processes the information sources from Scopus data using the key source from article title as hybrid ventilation. This analysis process running during October 2020. Starting years is 1981 as the first year of the paper with the title hybrid ventilation.

3. Result and discussion
This section discusses the results of the bibliometric analysis of Hybrid Ventilation. It is resulted 223 documents, consist of 130 article, 3 book chapter, 87 conference papers, 1 editorial and 2 reviews, from 125 sources as journals, books and etc. The publications during the time span of 39 years, from 1981 to 2020. The study was carried out on the publication output from 1981 to 2020, in order to see a more comprehensive trend over a fairly long span of 39 years. The number of studies published since 1981 to 2020 show the publication of hybrid ventilation has increased subsequent to 1999. In the first period, between 1981 to 1999, the paper's were less than 2 papers per year. In 2005, there was an increase publication to more than 10 papers per year with a tendency to increase. However, this increase in average published every 2 years can be seen from a sharp profile (see Fig.1). Regarding to the word growth in publication from 1991 in figure 2, it reveals that in this HV studies, numerical simulation as the fourth topic discussed after natural ventilation and hybrid ventilation itself.

Hybrid ventilation combines 2 ventilation systems as mechanical ventilation and natural ventilation. The biggest theme in this hybrid ventilation is dominated by natural ventilation compared to hybrid ventilation itself, especially mechanical ventilation. Figure 3 shows, the theme of hybrid ventilation itself relates to low building energy, energy performance, energy saving, energy consumption, IAQ, HVAC, comfort and indoor air. The strong theme of natural ventilation relates to simulations of the CFD, IAQ, wind, stack and atrium effects.
Related to this case, there was an increase in the variety of research that was selected from the variety and intensity of the words used. Although there has been an increase in hybrid publications, it is still dominated by natural ventilation. In comparison, the number of HV publications reaches 72 papers while NV studies dominated with 25 studies followed by thermal comfort, IAQ and numerical simulation. There are many opportunities in this area that have not been studied considering that the domain has an even wider scope than natural ventilation. Another ventilation represents displacement ventilation as a mechanical ventilation system mostly discussed.
Studies on HV were originally carried out in Europe, then dominated by research from China and USA. There only 20 countries were recorded have comprehensive research on HV, with total 223 documents, China contributed 31 documents, followed by the USA with 22 documents and UK 11 documents.

4. Conclusion
The result show, based on bibliometric analysis on 233 papers related hybrid ventilation from the Scopus database for the 40 years, there is an increasing trend in researchers towards hybrid ventilation in buildings. However, the number is still relatively small, so that it opens up opportunities for studies in this area, given the many advantages of using this hybrid ventilation. The trends discuss mostly natural ventilation, thermal comfort, IAQ and numerical simulation.

References
[1] IEA 2018b Key World Energy Statistics 2018
[2] Qi D, Cheng J, Katal A, Wang L and Athienitis A 2020 Multizone modelling of a hybrid ventilated high-rise building based on full-scale measurements for predictive control Indoor and Built Environment 29 4 496–507
[3] Vadmalraj N, Zingre K, Seshadri S, Arjunan P, and Srinivasan S 2020 Hybrid Ventilation System and Soft-Sensors for Maintaining Indoor Air Quality and Thermal Comfort in Buildings Atmosphere 11 1 110
[4] Annan G, Ghali K, and Ghaddar N 2016 Natural Ventilation in Beirut Residential Buildings International Journal of Sustainable Energy 35 996–1013
[5] Berchmans H, Suaib S, Augustina I, Panjaitan R, Winne 2014 Panduan Penghematan Energi di Gedung Pemerintah USAID www.iced.or.id
[6] Heiselberg P, Tjelflaat P O 1999 Design Procedure for Hybrid Ventilation The First International One day Forum on Natural and Hybrid Ventilation HybVent Forum (Sydney)
[7] IEA 2002 Hybrid Ventilation, State of The Art Review Energy Conservation in Buildings and Community Systems Annex 35 Hybrid Ventilation in New and Retrofitted Office Buildings ed A Delsante and T Arvid
[8] IEA 2002 Principles Of Hybrid Ventilation Energi Conservation in Buildings and Community Systems Programme Annex 35: Hybrid Ventilation in New and Retrofitted Office Buildings ed P Heiselberg
[9] Connick O 2013 The Fluid Mechanics of Hybrid Ventilation Imperial College London Department of Civil & Environmental Engineering
[10] Hamdy M and Mauro G M 2019 Optimizing Hybrid Ventilation Control Strategies Toward Zero-Cooling Energi Building *Frontiers in Built Environment* **5**

[11] Chen J, Augenbroe G and Song X 2017 Hybrid ventilation potential investigation for small and medium office buildings in different us climates under uncertainties *Proc. of the 34th International Symp. on Automation and Robotics in Construction Isarc* pp 894–900

[12] Durieux V and Gevenois P A 2010 Bibliometric Indicators: Quality Measurements of Scientific Publication *1 Radiology* p 255 342

[13] Massimo M and Corrado C 2017 Bibliometrix An R-tool for comprehensive science mapping analysis *J of Informetrics* Elsevier **11** 4 959-75