Hybrid ventilation systems on different climate

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Abstract. The building sector has an important factor in contributing to CO2 emission causes of global warming. The previous study showed that Heating, Ventilation and Air conditioning (HVAC) is the most dominant factor in building energy use. Reducing the heating or cooling load of buildings is the key for energy efficient building. The principle of hybrid ventilation is combining two different ventilation systems to reach thermal comfort, IAQ and reduce energy consumption. This paper review a hybrid ventilation (HV) system that applied on different location that refer to different climates. This paper conducted through literature review and brief discussion on system applied, the result and the background climate. The result show, based on the climate, there's a different hybrid ventilation system applied due to their effectiveness. In this study, in the temperate climates the HV can save energy up to 60-70%, hot arid 50% and warm humid 28%.

Keywords: Hybrid ventilation, Thermal comfort, Passive cooling, Warm humid tropics

1. Introduction
The building sector has an important factor in contributing to CO2 emissions through the use of fossil energy that main cause of global warming [1]. It consumes 40% of the world's energy sources [2]. The largest consumption in buildings is dominated for Heating, Ventilation and Air Conditioning (HVAC) purposes. The energy consumption reach as 47% in US [3], 40-44% in Lebanon [4], 40-45 in India [5] The study in Indonesia showed that air conditioning is the most dominant factor in building energy use, 84% in government buildings and 60% in other buildings [6]. Combining natural and mechanical ventilation in Hybrid Ventilation (HV) for indoor temperature cooling can achieve thermal comfort and reduced energy consumption. Hybrid ventilation is ventilation with natural and mechanical ventilation principles which together determine the air flow in the room [7]. Mixed ventilation / Hybrid ventilation is 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 [8][9] [10]. Hybrid systems strive to maximize the cooling potential from mixing outdoor air with indoor air, while using mechanical ventilation to ensure thermal comfort is maintained as long as outdoor conditions are not suitable for ventilation cooling. Therefore, reducing the heating or cooling load of buildings is critical to energy savings.

The HV approach is largely based on the use of mechanical ventilation (MV) with both air conditioning (AC) and without the cooling function and the utilization of natural ventilation (NV). This
is made possible by the existence of supportive outdoor climatic conditions so that it can be used to contribute to improving indoor air conditioning conditions [11]. Due to thermal comfort, the ventilation system will differ from one climatic condition to another. In temperate regions, occupants experiencing comfortable temperatures in spring and fall so can fully utilize NV. On summer, MV ensures the comfortable condition during the hottest summer day.

2. Method
Considering the energy efficient are important for the sustainable building, this paper reviews the previous studies that examine hybrid ventilation related to the climate. The reviewed studies are sources from internationally journals, relevant conference proceedings and study reports through search engines including Google Scholar, ScienceDirect, SpringerLink and Scopus index. This paper discussed through literature review and give a brief discussion about the ventilation system applied, the main method, the result and the background climate. Climate information, if not available in the paper, is classified by reference to the relevant authority, such as Europe area with The European Environment Agency as an agency of the European Union or any authorities. The climate discussion can be found in the table to review the comparisons and explanation points briefly.

3. Result and discussion
Hybrid ventilation were first and widely developed in Europe, by means of 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 [1].

In temperate climates with four different seasons the building can take advantage of mild season for natural ventilation. The temperature difference is large to response these changes both daily and monthly. There are several strategies have been implemented, such as changeover between natural ventilation and mechanical ventilation, NV as main system and additional MV a fan assisted natural ventilation or MV as main system, NV takes priority with Stack and wind supported mechanical ventilation. Solar chimney often used to increase air flow in NV performance and resulted 20% energy reduction in this climate [13] [14]. The study on refurbished school and office with the same comparation strategies giving the higher energy reduction in office building. In case of refurbished school building the energy saving reach 44-52% while in office building giving 60-70% compared to MV with three comparation strategies. The first as automatic NV and MV, the second is balanced MV with heat recovery system and the third is HV and heat recovery [15] [16]. The HV system have a significant energy reduction to 70% in temperate climate. The study on different schedule shows the higher energy saving is HV with variation schedule [17]. Study on thermal sensation on Adaptive Thermal Comfort (ATC) model as a control for HV and The Predicted Mean Vote (PMV) model is an objective control for cooler days [18]. Examining hybrid ventilation on four-season climates shown that it can achieve up to 50% and improve IAQ [19].

Study conducted in hot arid, using different application of radiant, evaporative and ground coupled cooling resulted energy efficiency as 50% [20], another study confirms ACS as a parameter for comfort especially in hot climates. Study in warm humid tropics confirm the HV and NV occupants have a higher temperature tolerance than MV. MV and cross ventilation strategies in HV showing the saving energy as 27.92% [21] [22]. Hybrid ventilation study in Jakarta climatic data discuss the design of window openings and opening schedules based on ACH, to optimize fresh air in residential types with natural ventilation based on wind speed [23].

4. Conclusion
The result show, based on the climate there should be a different hybrid ventilation system applied due to their effectiveness. Due to the location, mostly hybrid ventilation on four-season climate, where there are summer and winter cycles, employ more ventilation strategies due to natural ventilation. There were some systems applied on Hybrid ventilation due to natural ventilation as solar chimney with ventury roof and motorized open window. Mechanical ventilation applied displacement ventilation system and air box converter. By applying hybrid ventilation, the potential for energy generation is: 70% in offices, and 52% in schools in temperate climates. 50% in hot arid climate and 27.92% in humid tropical climate.
In temperate climates, the strategy used is to maximize the climate potential in a season that has comfortable temperatures either with MV devices installed or by maximizing natural ventilation. In dry tropical climates, potential savings are achieved by tolerating a comfortable temperature and implementing a cooling strategy. In humid tropical climates, the saving energy as much as 27.92% with a combination of natural ventilation only.

**Table 1. Hybrid ventilation system in different climate**

| Ref      | Location          | Climates    | Hybrid system                                                                 | Information                                                                 |
|----------|-------------------|-------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Wouters  | Europe            | Temperate   | 3 basic strategies, 5 HV system.                                             | 4 integration systems: Industrial HV system, Fully integrated design, Moderate, Marginal. |
| Engel    | Europe            | Temperate   | a solar chimney and exhaust with a venturi-roof heat recovery                 | *20% energy reduction*                                                      |
| Aliabadi | Vancouver, Canada | Temperate   | In cooling mode: a hanging fan-less displacement ventilation strategy.        | In heating mode, use a ceiling fan, pushing down warm air, and a low-level by pass exhaust. Radiant heating / cooling is recommended. |
| Fu       | China Nanjing     | Temperate   | window-opening machine for natural ventilation and fans for mechanical ventilation. | ACS as a control for VH. The PMV model is an objective control for cooler days. |
| Li       | China             | Temperate   | Natural ventilation with solar chimney on classroom.                          | Simulation study on Solar chimney to improve hot pressure effect that increase vent rate. |
| Steiger  | Munich, Copenhagen London. | Temperate | Automatic NV Balanced MV with heat recovery HV and heat recovery              | Refurbished school building. *HV have energy savings of 44-52%, compare with MV*. |
| Steiger  | Munich, Copenhagen London. | Temperate | Automatic NV Balanced MV with heat recovery HV and heat recovery              | Office 60-70% compared with MV. Reducing CO2 emission by 60%.                |
| Jrejiry  | Greece, Sweden    | Temperate   | Mechanical extract and hybrid low pressure                                   | decrease 50% CO2 while reducing 90% the fan electrical energy.               |
| Akira    | Japan             | Temperate   | The heat recovery system ventilation and MV.                                 | combines passive stack                                                      |
| Hamdy    | Glasgow scotland  | Temperate   | 3 HV strategy against MV, chimney vent for cross ventilation.                | Minimizes cooling requirements to 0. Heating, saving 68% AHU fan. More comfort and a higher IAQ level. |
| Sultana  | Canada            | Temperate   | Scheduling of window opening with HV motor in NZEB building                  | HV energy saving 10-20% with fixed schedule, 65% schedule variation.       |
| Cui      | Shanghai          | Sub tropic  | integrates radiant cooling panel, decentralized ventilation and an airbox     | Cooling capacity is increased by 7.1%, least energy consumption.             |
| Rowe     | Sydney            | Sub-tropic  | NV through the core and windows, equipped with reverse cycle refrigerated     | Increases the perception of thermal comfort and air quality depending on the |
Table 1. Hybrid ventilation system in different climate (contd)

| Ref     | Location       | Climates       | Hybrid system                  | Information                      |
|---------|----------------|----------------|-------------------------------|----------------------------------|
| Ezzeldina[20] | Egypt, Hot Arid | Cooling : Radiant, Evaporative, Ground Coupled cooling | Hybrid Energy efficiency: 50%     |
| Khalil[30] | Beirut, Libanon | Hot arid       | HB with personal ventilation   | Setting temperature on 29°C       |
| Lau[21]  | Singapore      | Warm humid     | HV and NV occupants have a higher temperature tolerance |
| Hommod[22] | Kuala lumpur   | Warm humid     | HV with crossventilation       | Saving energy 27.92               |
| Soebiyan[23] | Jakarta       | Warm humid     | HV based on ACH               | Perdicted opening design         |

References

[1] Ji Y, Lomas K J and Cook M J 2009 Hybrid ventilation for low energy building design in south China Building and Environment 44 11 2245–55.
[2] IEA 2018 Key World Energy Statistics 2018
[3] 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
[4] Annan G, Ghali K, and Ghaddar N 2016 Natural Ventilation in Beirut Residential Buildings International Journal of Sustainable Energy 35 996–1013
[5] Vadamalraj N, Jingre 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
[6] Berchmans H, Suabi S, Agustina I, Panjaitan R, Winne 2014 Panduan Penghematan Energi di Gedung Pemerintah USAID www.iced.or.id
[7] Connick O 2013 The Fluid Mechanics of Hybrid Ventilation Imperial College London Department of Civil and Environmental Engineering
[8] 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)
[9] IAEA 2002 Hybrid Ventilation State of The Art Review Energi Conservation in Buildings and Community Systems Annex 35 Hybrid Ventilation in New and Retrofitted Office Buildings ed A Delsante and T Arvid
[10] IAEA 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
[11] Chikamoto T, Kato S and Ikaga T 1999 Hybrid Air-Conditioning System at Liberty Tower of Meiji University Technical paper HybVent Forum 99 (Sydney)
[12] Kwon O H, Kim M H, Choi A S and Jeong J W 2013 Energi saving potential of a hybrid ventilation system integrated with heat storage material Energi and Buildings 57 346-353
[13] Wouters P Heijmans N Delmotte C Vandaele L 1999 Classification of hybrid ventilation concepts Belgian Building Research Institute
[14] Engel V D P, Kemperman R and Doolaard H 2012 Natural and hybrid ventilation principles based on buoyancy, sun and wind J REHVA 201 25–32
[15] Steiger S and Roth J K 2017 Hybrid ventilation in new and refurbished school buildings The future of ventilation 38th AIVC Conference 6th Tight Vent Conf.
[16] Steiger S and Roth J K 2017 The future of hybrid ventilation in office buildings Energy simulations and lifecycle cost 38th AIVC Conf. 6th Tight Vent Conf.
[17] Sultana S, Athienitis A K and Zmeureanu R G 2019 Improving Energy Savings of a Library Building through Mixed Mode Hybrid Ventilation. Proc. 23 1 3
[18] Fu X and Wu D 2015 Comparison of the efficiency of building hybrid ventilation systems with different thermal comfort models Energy Procedia 78 2820–25
[19] Hamdy M and Mauro G M 2019 Optimizing Hybrid Ventilation Control Strategies Toward Zero-Cooling Energi Building Frontiers in Built Environment 5

[20] Ezzeldin S and Rees S J 2013 The potential for office buildings with mixed-mode ventilation and low energy cooling systems in arid climates Energy and Buildings 65 368–81

[21] Lau S S Y, Zhang J and Tao Y 2019 A comparative study of thermal comfort in learning spaces using three different ventilation strategies on a tropical university campus Building and Environment 148 579–99

[22] Homod R Z and Sahari K S M 2013 Energy savings by smart utilization of mechanical and natural ventilation for hybrid residential building model in passive climate Energy and Buildings 60 310–29

[23] Soebiyan V, Sjarifudin F U and Efendi J 2016 Study on Green Vertical Housing Using Hybrid Ventilation System Based on Air Changes per Hour Factor Applied Mechanics and Materials 835 423–28

[24] Aliabadi A A, Faghani E, Tjong H A R and Green S I 2014 Hybrid Ventilation Design for a dining hall using computational fluid dynamics (CFD) Proc. of The Canadian Society for Mechanical Engineering pp 1–6

[25] Li J and Li D 2015 The Study on Numerical Simulation of Classrooms Using Hybrid Ventilation under Different Solar Chimney Radiation Procedia Engineering 121 1083–88

[26] Rejijiry D, Husaunndee A and Inard C 2007 Numerical study of a hybrid ventilation system for single family houses Solar Energy

[27] Fukushima A, Murata S and Uozumi M 2017 Heat Recovery Hybrid Ventilation System With a Thermal Storage 38th AIVC Conference 6th Tight Vent Conference

[28] Cui S, Kim M K and Papadikis K 2017 Performance Evaluation of Hybrid Radiant Cooling System Integrated with Decentralized Ventilation System in Hot and Humid Climates Procedia Engineering 205 1245–52

[29] Rowe D and Dinh C T 2001 An experiment with hybrid ventilation A more sustainable approach to thermal comfort Architectural Science Review 44 2 127–133

[30] Khalil S Ghali K Ghaddar N and Itani M 2020 Hybrid mixed ventilation system aided with personalised ventilation to attain comfort and save energy International Journal of Sustainable Energy 39 10 964–81