CHAPTER 1 INTRODUCTION

1.1 Research Background

Since the industry revolution, people had been learnt to create systematically more and more enormous inventions including growth of population that have led to the increase of the energy consumption all over the world. This phenomenon has conduced to worse effects of the world environment, for instance, pollution, waste, and carbon dioxide emission. They became global warming which is the considerable problem in the current decade. The industrial segment is one of the significant causes of carbon dioxide emission into the world atmosphere. Fortunately, it can be decreased by attempting in renewable energy usage, such as solar energy and wind energy to generate power for the buildings integrated with the energy-efficiency strategies in the way of passive design, including realization of polluted environment and manipulation of energy consumption for the sustainability of future human resources that should be considered; that there is more than thirty percent of end-use sectors shared of total consumption from industrial sector [EIA, 2008]. In the past, the development of design strategies in thermal comfort for the building has been dominated by the independent variables consisting in function, economics, culture, and design trend. It is just recently mentioned in integrated design strategies in energy efficiency to employ less mechanical methods and enhance more natural methods for the energy consumption while still retaining thermal comfort for the occupants.

For architects, the complexity of visualization and quantifying energy consumption are the barriers that had restricted them in designing for energy-efficient buildings at the preliminary design, the beginning of design stage. It could be the task accomplished by the engineers after preliminary design has been completed. In order to do better, the effective simple tools and methods should be available to assist architects for designing energy efficiency of buildings at the beginning of design [Knowles, 1967]. In addition, recently, there are a lot of standards or recommendations for architects to guide method of saving energy from various organizations, for instance, ASHRAE (The American Society of Heating, Refrigerating and Air-conditioning Engineers), LEED (Leadership in Energy and Environmental Design), the green building rating system, developed by the U.S. Green Building Council (USGBC) of the United State of America, BREEAM (Building Research Establishment Environmental Assessment Method) of the United Kingdom, and CASBEE (Comprehensive Assessment System for Built Environment Efficiency) of Japan. In Thailand, there are also TEEAM (Thailand Energy and Environmental Assessment Method) by Ministry of Energy and TREES (Thai Rating Energy and Environment System), in cooperation with the Council of Engineers, Council of Architects and other involved organizations. The new evaluation criteria for green buildings or energy-efficient buildings, is still under technical hearing from all parties involved to establish the institute that will be significantly recognized for brand image and additional value to business. However, these standards or recommendations should be properly decided by commencing on concept design, detail design, construction, and maintenance in order to achieve energy saving and friendly environment for building design in Thailand.

Studying the new technologies of the energy efficiency, analyzing the theories of the energy saving, and applying to achieve the most effective energy saving in the actual projects, are the better ways to reduce such problems of polluted environmental effects. In addition, industrial buildings in tropical climate have potentials to utilize the naturally renewable energy integrated with passive design from the beginning stage by using building orientation, natural ventilation, daylighting, building envelope, and solar energy to generate some electricity while decreasing some electric consumption in lighting and HVAC in daytime, in order to improve the quality of occupants' life and to conserve energy resources for the next generation. This thesis is expected to develop design strategies for more efficient energy consumption and motivate manufacturers to realize the significance of less energy consumption, to pay more attention to improve desirable surroundings and to create the friendly environment in sustainable industrial buildings.

1.2 Objectives

The objectives of this thesis are greatly to propose the integrated design strategies of thermal comfort in industrial building design which was a few researches in terms of improving architectural design and thermal comfort in Thailand. To achieve this goal, the follows are defined:

1. To investigate the potential of energy usage in industrial buildings, which can be decreased by simulating through the application tools.
2. To develop the passive design strategies in terms of industrial building design that integrates into the sustainable buildings.
3. To analyze and propose the guideline of integrated design strategies in thermal comfort for particularly heat generated industrial buildings which is appropriate to tropical climate.

1.3 Scopes of Research

This research focuses on passive design for industrial building appropriate for tropical climate particularly in Thailand that can be applied in another locations whose climate are alike. However, merely the passive design might not be sufficient to achieve thermal comfort, because of uncertain limitation of the outdoor air condition. Therefore, the scopes will be aimed to enhance advantages of natural energy characteristics and possibly employ minimized mechanical system in industrial buildings. There are limited scopes of the study as follows:

1. To study natural ventilation for industrial buildings which have individual characteristics of large size and wide span. buildings in Thailand, consisted of the following:
2. To study daylighting in industrial buildings conformed to the energy saving potential, visual characteristics, and control of solar radiation.
3. To study building envelope of industrial buildings to protect the indoor environment and facilitate climate control.

1.4 Significance of the Study

It has been found that a few studies in industrial buildings in terms of architectural design are involved with passive design and naturally renewable energy. Thus, this research had been intended for a contribution in the fields of design and operation guidelines for industrial buildings in tropical climate such as Thailand. The results of the study will be expected to the follows:

1. The guideline of energy saving techniques for industrial buildings to be more suitable and effective in tropical climate like Thailand would be developed.
2. The guideline of desirable environment in buildings including human comfort to improve quality of occupants' life would be motivated.
3. The theories of thermal comfort and energy saving could be applied for the standards and regulations of energy conservation to actual practices in industrial buildings design.

1.5 Literature Review

The previous literatures involved in this research had been gathered merely in categories of passive design and minimized active design for passively tropical industrial buildings that will be reviewed as follows:

1.5.1 Building Orientation

Determining optimized building orientation for naturally ventilated buildings is important to minimize the number of weather events where the ventilation rates are below the summer design ventilation rate [Zemanchik, 1992]. For ten regional weather stations across the province of Ontario, difference methods were exploited to obtain the preferred building orientation which contained the average ventilation rate method, the percentage of ventilation rates above and below the minimum summer ventilation rates, and the consecutive hour's method. The analysis involves six building orientations (0°, 30°, 60°, 90°, 120°, and 150 °) with respect to the north, and exterior temperatures equaling or greater than 20°C, 25°C, and 30°C. He found that the orientation of 150° off the north would be the preferable building orientation, based on the results obtained from the ventilation rate frequency histograms. The output of the statistical analysis had revealed that for the mentioned temperature range, there is a relationship between the ventilation rates below the design summer ventilation rate and building orientation.

Table 1.1 Ottawa weather station's average ventilation rates and standard deviation greater than mentioned temperatures for building orientation angles 0°off the north. [Zemanchik, 1992].

Building Orientation (Angle off North)	Average Ventilation Rate (L/s)	Standard Deviation
Temperature ≥ 20°C		
0	20 364	13 311
30	19 102	12 428
60	19 237	12 166
90	19 997	12 781
120	21 226	13 478
150	21 668	13 680
Temperature ≥ 25°C		
0	23 057	13 525
30	20 699	11 924
60	20 785	11 730
90	22 399	13 174
120	24 542	14 368
150	25 164	14 375
Temperature ≥ 30°C		
0	27 700	13 368
30	24 190	11 843
60	22 651	10 553
90	23 864	11 853
120	27 377	13 427
150	29 441	13 675

Therefore, from this study it will be a starting point for simulation to orient the building in longitudinal side crossing perpendicularly against the wind direction.

1.5.2 Naturally Ventilated Buildings

Atch Sreshthaputra investigated the indoor thermal conditions of naturally ventilated buildings in tropical climate presenting Thai Buddhist temples as two case-study buildings, a new and an old one. He analyzed the indoor thermal conditions and airflow characteristics in the case study by using computer simulations calibrated with collected data measurement [Sreshthaputra, 2003]. A methodology was developed for creating a simulation model of a Thai Buddhist temple to correctly represent the real building that could be used as a base case for parametric studies along with combination of thermal/CFD simulations. It was found that both of the case study temples were not comfortable most of the time, especially in the summer when it was hot and humid. The measurements also revealed that the old temple was more comfortable than the new temple. However, the indoors seemed to be warmer than the outdoors during the night because the walls that absorbed heat in daytime transferred heat to inside the temple. In terms of building heat gain, the major heat gain component was found to be the attic heat, and a lesser extent heat from envelop conduction. The results also suggested that the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) recommended surface convection coefficients are excessively large; smaller values could be obtained using a numerical method [Sreshthaputra, 2003]. He addressed the high-mass prototype for renovation of older buildings and the low-mass prototype for new buildings. Finally, he proposed the building design and operation guidelines for improving thermal comfort in tropical climate that consisted of increasing wall and ceiling insulation, a white and low absorbed roof, a slab-on-ground floor, shading devices, nocturnal ventilation, 24-hour attic ventilation, wider windows, wing walls with vertical fins, and dehumidification system.

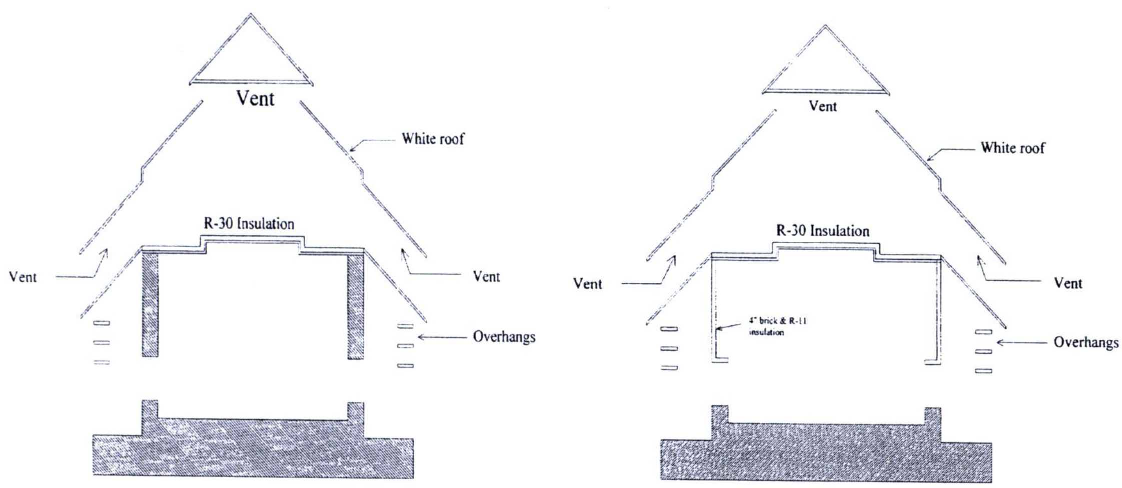

Figure 1.1 Section view of the old temple (left) and the new temple (right) [Atch Sreshthaputra, 2003, p.153].

The improvement of natural ventilation in a large factory building using louver ventilators, studied by Jong-Hoon Kang, and Sang-Joon Lee, revealed that when heat generated from facilities inside a large factory building was not discharged into outside the building as a result of a stagnant ventilation flow, the working environment of workers became worse and the cooling of high-temperature products was delayed. The wind tunnel tests were conducted to investigate the natural ventilation of entrained air inside a large factory building. The scale-down factory building models were embedded in a simulated Atmospheric Boundary Layer (ABL), and the mean and fluctuating velocity fields were measured using a two-frame Particle Image Velocimetry (PIV) technique. For the original factory model, some of the outdoor air came in the factory building through the one-third open windward wall, while the stagnant flow region existed in the rear part of the target area. In order to improve the indoor ventilation environment of the present factory building, three different types of the louver ventilator were attached at the upper one-third open windward wall of the factory model.

Comparing with the three louver ventilators, it is found that the ventilators with the outer louvers (θ_o = 90°) and the inner louver (θ_i = -70°) were the most improve the natural ventilation inside the target factory-building model [Kang and Lee, 2008]. The flow rate of the entrained air could be increased by aligning the outer louver blades with the oncoming wind and guiding the entrained air down to the ground surface with the elongated inner louver blades.

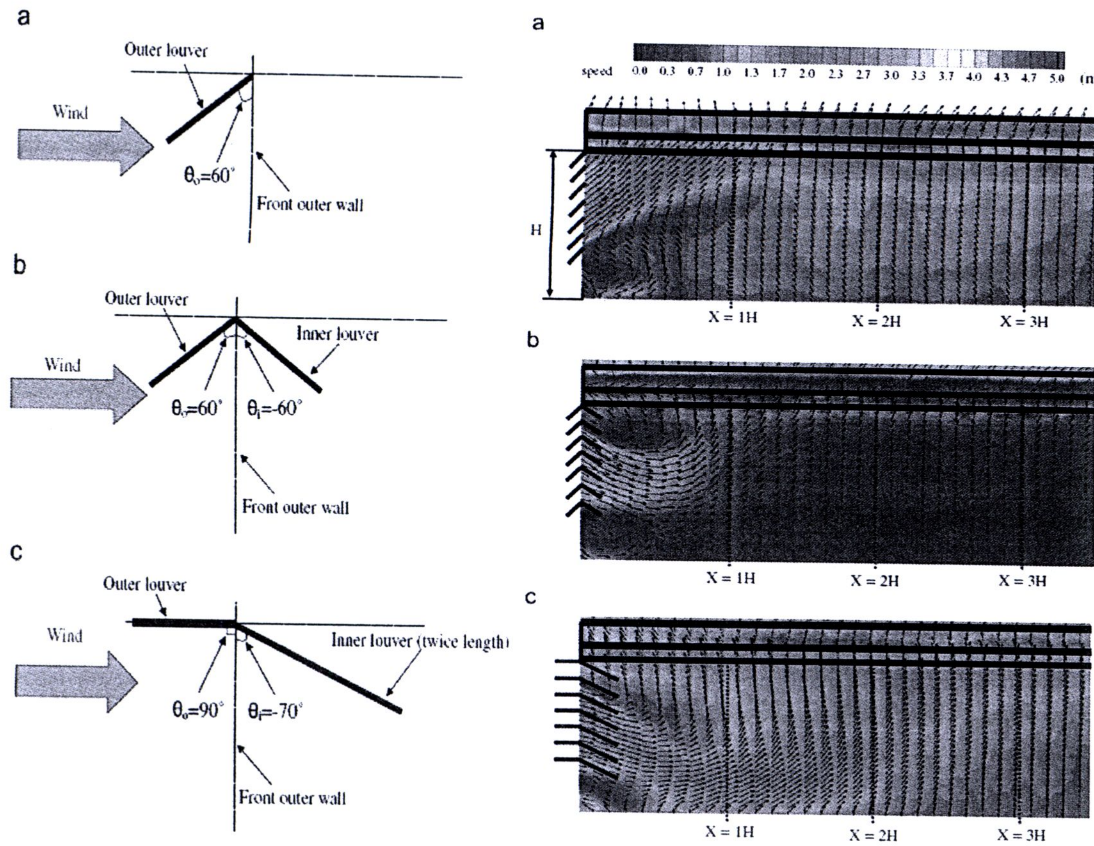

Figure 1.2 Mean velocity field distributions inside the modified factory models in different types: a, b, and c.[Kang J.H., Lee S.J., 2008].

1.5.3 Thermal comfort for Thailand

In the journal of cool condition for Thai traditional architecture in passive way cited by Thanit Chindavanig, Thai traditional architecture that had been developed for a long time could be approached to comfort zone which was appropriate to tropical climate by improving internal conditions passively such as using natural ventilation, preventing direct sunlight and thermal radiation transferred to building envelope, and decreasing heat transfer from surrounding materials exposed to the sun including insulation and low U-factor value. Even though in summer it could not gain the western standard of comfort, acclimatization and adaptation could allow Thai people to be comfortable in passive way. Among the comfort factors, MRT of surrounding surface temperature affects to human sensation rather than air temperature 40% [Chindavanig, 1997]. Whenever Mean Radiant Temperature (MRT) of surrounding surface temperature is higher than human's skin temperature (32 °C), it will transfer heat radiation to human body that makes human feel hot. He suggested that the better microclimate such as shading of big trees could reduce temperature lower than outside air temperature about 3°C. Furthermore, he explained that air velocity was related to thermal comfort zone. When air temperature was out of comfort zone, increasing air velocity could conduct the thermal comfort to the human due to wind flowing against human surface will increase the heat loss ratio from evaporating perspiration that makes human body cool.

1.5.4 Daylighting for Tropical Buildings

Thotsaphon Saengsuwan experimented to determine the practical form, texture, size, and shape, including the glares protection for window design in the classroom of a primary school building in Thailand [Saengsuwan, 2006]. The experimental models were tested under the sky to analyze the daylight factors resulting in an amount of light in a classroom all year round. He examined an approach of the design of windows as light shelves to improve the daylighting efficiency in the educational buildings that helped increase the illumination value to meet the standard and visual comfort by the least electric lighting. The results revealed that the educational buildings should have additional three parts of window. The first part was a casement window, installed at 0.75-1.45 meters from the floor. The second part was a 0.6-meter-wide hanging window, in white tilted placed 10 degrees to the horizontal line at 1.45-2.05 meters from the floor. And the third part was a 6 mm-clear glass-thick with fixed window, installed at 2.05-2.90 meters from the floor. This three-part window brought the reflectance efficiency with daylight factor of 2% at the innermost area [Saengsuwan, 2006].

The report of an investigation into the relationship between daylighting and human performance for PG&E (Pacific Gas and Electric company), conducted by Heschong Mahone Group, demonstrated that skylighting associated with higher sales for the store. It increases productivity in a manufacturing building, improves morale in an office building, and reduces absenteeism at a postal facility. Because the customers perceive cleanness from skylighting, they are more relaxed and motivated to spend more time in a store shopping, with better visible to comfortably select the products in high daytime illumination levels, and more attractive products inducing to buy [Heschong Mahone Group, 1999]. Moreover, it reveals that the employees also have higher morale to work for the company and finally provide the better service to customers. Skylight area ratio which balanced the lighting illumination and heat gain should be investigated.

1.5.5 Building Envelope for Tropical Buildings

During the preliminary stage of a building's design, the architect deals with the general geometrical factors related to the building's shape including the building's height in relation to street dimensions, facade orientation, and the building's proportions. I. Guedi Capeluto, studying the energy performance of the self-shading building envelope, proposed the Solar Collection Envelopes (SCE) concept to generate the self-shading envelope of the building. Its solar potential of the building and the surrounding areas is determined, assuring the exposure of the elevations and sidewalks to the winter sun, and creating the appropriate shading during the critical hours of the summer days to achieve an energy-saving design of the building. He addressed that designers and planners might derive graphic and numeric output immediately for the design of different geometric variations based on the SCE, in an accurate and easy way. This design tool could also be used at an urban level with the purpose of determining the profile of the streets so as to obtain shadowed sidewalks and facades during a required period at summer and expose them to the winter's sun. The required period might be limited particularly during the early morning and late afternoon hours to avoid extremely sloped walls. Since solar gains during these hours could be significant in summer, an additional shading program might be determined for each of the facades. Facade orientation has an important effect on the envelope form and wall inclination demonstrating the influence of rotating the building by 30° from the north [Capeluto, 2003]. This research includes a detailed example of the implementation of the method, and the evaluation of the influence of the proposed building geometry on the energy performance of the building, based on a comparison with a traditional vertical facade building. The simulation result revealed that for all the orientations there is an important improvement in the energy performance of the building when designing correlates with the self shading envelope. Similar results can be also obtained for vertical facades using high-performance low-emission windows. The combination of the building self-shading geometry and internal blinds provide the best solution, particularly for east and west orientations.

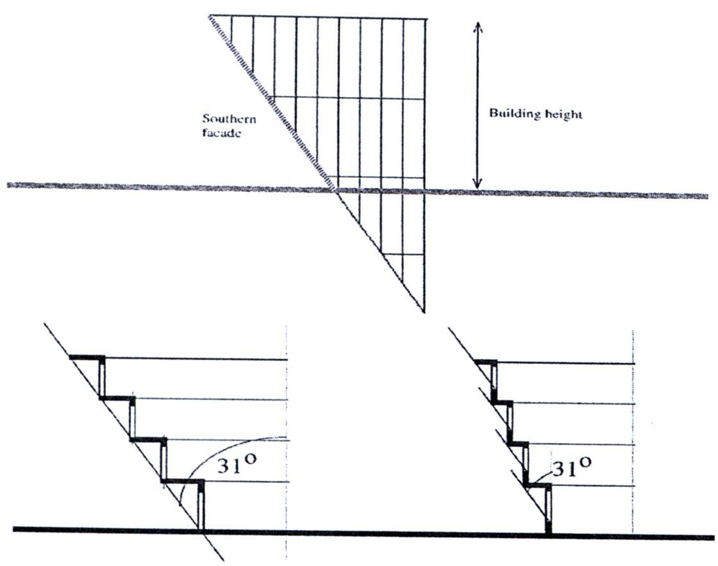

Figure 1.3 Two proposed design alternatives for the southern facade according to the SCE [Capeluto, 2003].

J-ray Suwannachart, studying the roof efficiency development to decrease thermal transfer value in a superstore in Bangkok, examined and found that the large building and tiny tilted roof that almost perpendicular to the sun all day such as in a superstore would transfer solar heat into the building more than that from the facades because of their great area facing the sun directly. He suggested that the plenum between roof and ceiling should be ventilated regarding air movement from the different temperature by assisting of natural roof fan system and design of volume of plenum as well. To improve roof efficiency, the roof insulation system should be properly selected with open system, which has space between roof sheet and insulation, comparing with the calculation of conduction, convection, and radiation from solar heating [Suwannachart, 2001]. As a result, the thermal transfer value in a superstore had been decreased previously two times and the several cooling loads of air conditioning had also been reduced.

The influences of the external walls of thermal inertia on the energy performance of well insulated buildings were investigated by a group of Italian researchers, Nico Aste, Adriana Angelotti, and Michela Buzzetti. It was revealed that energy conscious building design consisted of the controlling of the thermophysical characteristics of the building envelope such as, firstly, thermal transmittance (U-value). In addition, the envelope thermal inertia should also be considered. The studies reported very different estimations regarding the energy saving potential associated with the use of an adequate inertia, ranging from a few percentages to more than 80%. Therefore, this study aimed at assessing the parameters enhancing or damping the role of thermal inertia, providing a variety of results. For this purpose, several external wall systems with the same U-value but different dynamic properties were investigated to calculate the associated achievable energy savings. A parametric analysis was performed in progressive steps, by running the models of a virtual test cell and of a sample building. Both design parameters (heat transfer surface, solar control) and operational ones (ventilation rates, HVAC functional regime) were varied. On the basis of the analysis performed, it could be observed that there was difference between the heating demands with a low inertia wall comparing with a high inertia one might reach approximately 10%. The difference between the cooling demands with a low inertia wall comparing with a high inertia wall might reach approximately 20% [Aste, et al., 2003]. In conclusion, it was found that the highest energy performance wall system had a proper combination of the dynamic thermal transmittance and thermal admittance values, although not necessarily the best. Moreover, it was shown that thermal inertia effects were enhanced if they were coupled with other energy saving measures and efficient building use. Therefore, these should be applied material with low U-value to roof design for this research due to its most effect to building envelope.

1.5.6 Photovoltaics and BIPV for Alternative Energy Resources

Sirikul Prasitpianchai from International Institute for Energy Conservation (IIEC), who studied the solar thermal market in Thailand, had a lecture in Renewable Energy Conference in Bangkok. She addressed that the market potential of solar thermal in Thailand is approximately 1.5 million m^2, where as the Thailand energy saving potential is approximately 153 ktoe or 0.24% of TFEC 2005, and potential of carbon dioxide emitted reduction were 450,000 ton/year [Prasitpianchai, 2007]. Comparing with the other international countries which succeed in the energy saving, subsidization from the government is requisite to promote the market increasing at the early stage. And quality is the key to sustainable market to find the new suitable solar energy system.

Photovoltaic cogeneration in the built environment had been investigated by a group of Dutch researchers consisting of Morgan D. Bazilian, Frederik Leenders, B.G. C. Van Der Ree, and Deo Prasad. They evaluated that using the waste heat and available daylight from PV modules was an elegant idea, and had been successfully installed and operated in a number of commercial and industrial facilities. From the technological perspective, PV thermal systems are especially suitable for low temperature. For medium-temperature applications, the thermal and electrical yield of the hybrid system is lower than that of two separate systems. The combination of the two will always be a compromise. Hence, a PV thermal system is economically viable when the costs of the reduced energy performance matched the gained costs of production, installation, and mounting. Apart from the economic motive, the uniform appearance of a PV cogeneration system may provide an important surplus value in terms of enhanced architectural aesthetics. A PV cogeneration system will also serve to meet the consumer's desire for solar energy to meet both thermal and electrical loads [Bazilian, et al., 2001]. The PV thermal facade might be an attractive niche market as a PV thermal facade features architectonic possibilities and can displace several building materials. Economic and technical performance are strongly related to climatic conditions, building energy loads, system energy production, and the amount of materials saved. Domestic hot water PV thermal systems are currently not profitable. However, this product could have large market volumes and is expected to emerge to a mature market within a relatively short period of time, as interest in BIPV and thermal systems in the domestic market is growing fast. PV cogeneration should be researched and installed in a holistic manner. By taking into account the benefits of electrical, thermal, and daylight production systems, they can appear more attractive, both economically and environmentally. With the growth and interest in BIPV and, more generally, in distributed energy systems and cogeneration, PV cogeneration could play a large role in future PV installations at every level of the built environment.

Prinyo Wajarat and Worawut Kawong had experimental measurement in three characteristics of roof and found that the temperature of metal roof would be 33~39°C; the temperature of corrugated roof was 33~40°C, while the temperature of solar panels were 28~32°C [Wajarat, and Kawong, 2007]. It indicated that the roof area under solar panels had the lowest temperature, because of its more thermal resistant and solar heat loss through solar panel before being transfer red to attic space under the roof. Therefore, their potentials of PV and BIPV should be considered alternatively for the manufacturers to save energy and for the further study of the researches.

1.5.7 Integrated Building Design in Energy Efficiency

A low-speed wind tunnel experiment is conducted to investigate the prototype's ventilation performance in Chi-Ming Lai's research, on the concept of integrating energy demands of the ventilator with renewable energy to achieve an optimum electricity generation and to reduce energy consumption. In Taiwan, autumn and winter are the peak seasons for wind energy, while spring and summer are the low periods. Therefore, the maximum benefit of natural resources can be obtained by measurement such as adapting to local conditions, complementing of multiple energy sources and using integrated applications. The experimental results indicated that installing an inner fan at low outdoor wind speed (0 and 5 m/s) had increased the ventilation rate; the ventilation rate enhancement per inner fan rotational rate increment was found to be 2.44 and 2 CMH/rpm, respectively [Chi-Ming Lai, 2005]. However, the ventilation rate was not improved by installing an inner fan at a high outdoor wind speed. Installation of the inner fan with the rated rotation speed close to 1500 rpm is highly recommended by this research. The widespread application of turbine ventilators in Taiwan focuses on the building ventilation and industrial ventilation.

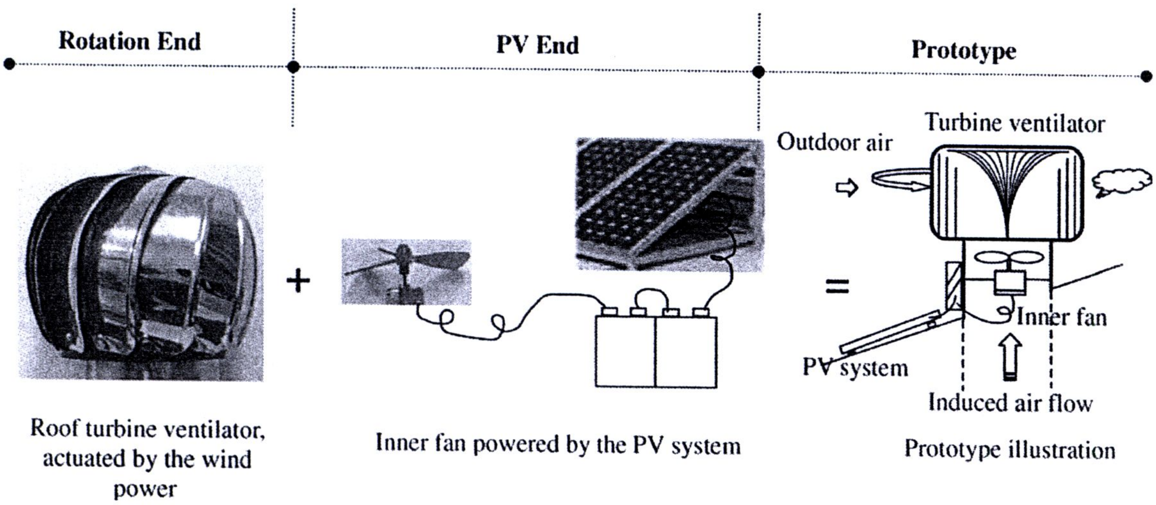

Figure 1.4 Illustrative diagram of the roof turbine ventilator proposed in Chi-Ming Lai's research.

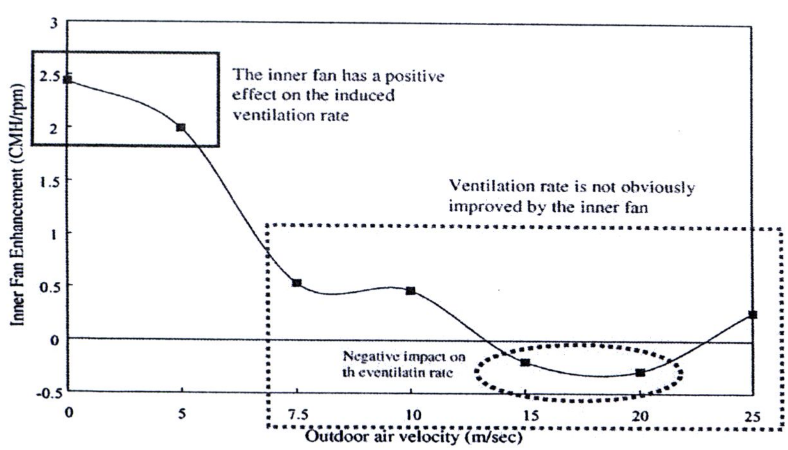

Figure 1.5 Inner fan enhancement of different outdoor air velocity [Chi-Ming Lai, 2005].

In summary, some of the previous literatures had already studied about the energy-efficiency strategies in passive design for tropical buildings, which are implicated in this thesis. For instance, the indoor thermal conditions for naturally ventilated buildings in tropical climate by Atch Sreshthaputra, and the improvement of natural ventilation in a large industrial buildings employing louver ventilation by Jong-Hoon Kang and Sang-Joon Lee. And some studies in minimized active design had been examined such as installing an inner fan at low outdoor wind speed powered by PV system to increase the ventilation rate by Chi-Ming Lai. These will be useful for the thesis studied in the adjacent way. In addition, it will investigate more integrated strategies of energy efficiency in passive design to the greatest extent in industrial buildings, one of the most carbon dioxide emission activities, appropriate to Thailand.