Wind Engineering Joint Usage/Research Center
FY2017 Research Result Report

Research Field: Indoor Environment
Research Year: FY2017
Research Number: 172007
Research Theme: Housing Envelope Design for Adapting Heat Stress under Climate Change

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*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
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1. Research Aim

IPCC AR5 defining the determination of risk are hazard, exposure and vulnerability. It is showed that the increase of nature disaster frequency will cause the much more hazard and exposure when climate change like heat wave and cold surge. So, susceptible populations, who are more vulnerable to temperature exposure, are most likely to be harmed under the impact of climate change.

Recently, with the frequency of extreme event has gradually increased in many cities worldwide, lots of studies focused on the health risk which lead by dramatic changes of climate. As showed in Table 1, many research focused on the relationship of temperature and mortality found that most of the effects of temperature on mortality are U-shaped or V-shaped, which indicating that extreme temperatures will lead to an increase in mortality no matter in the countries of the temperate latitudes (Bunker et al.,2016 ; Braga et al.,2002) or subtropical latitudes (Ma et al., 2013; Lin et al.,2011; Lin et al.,2013).

In addition, most research of the impact of climate change on indoor environment were focused on thermal comfort and policy suggestion of energy. Huang et al. (2016) analysis the annual cooling energy use with EnergyPlus and found that cooling energy will increase 31%, 59%, and 82% in 2020s, 2050s, and 2080s relative. Then, five passive design strategies for building remodeling are proposed, and their potential for mitigating the increases in cooling energy usage is discussed.

However, rarely research applied temperature-related health risk to evaluate the effect of residential adjusting strategies where susceptible populations spend most of their live. With intensifying extreme events expected in the future, evaluating the residential health risks associated with hot and humid climates, such as that in Taiwan, is worthwhile. In this study, the effectiveness of multiple building envelope strategies on adapting indoor temperature and reducing health risk as countermeasures to the changing climate was be quantified .

2. Research Method

2.1 The building model of simulation

In this study, a dynamic building simulation software, EnergyPlus, was used to simulate the daily maximum temperature and minimum temperature of indoor environment all over the year. A row-house which is a kind of typical townhouse in Taiwan that the individual houses share adjacent walls in common and have high window-wall ratio with narrow and deep architectural design was selected. The layout of the plan, which is considered typical of the row-house, is showed in Fig. 5. It is located in Taipei with a latitude of 25˚04’ north and longitude of 121˚507’ east.

The unit located on the top floor and in the west was selected to carried out the analysis in order to examine the most vulnerable case, which will have more exterior surface area exposed to the outdoor climate than the units lower, to find proposed countermeasures capable of reducing health risk. The U-value of the roof was set to 1.08 W/m^2K which is equivalent to 150mm reinforced concrete construction and 10mm waterproof material. The U-value of exterior wall was set to 3.16 W/m^2K, equal to 200cm reinforced concrete construction and 10mm tile. The glazing properties of sliding sash window were 5.9 W/m2K for U-value and 0.9 for solar heat gain coefficient. The discharge coefficient of window with screens was set as 0.4 for the calculation on natural ventilation, and the set-point to close window was set to 21˚C which is equivalent to the threshold of overcooling in this study.

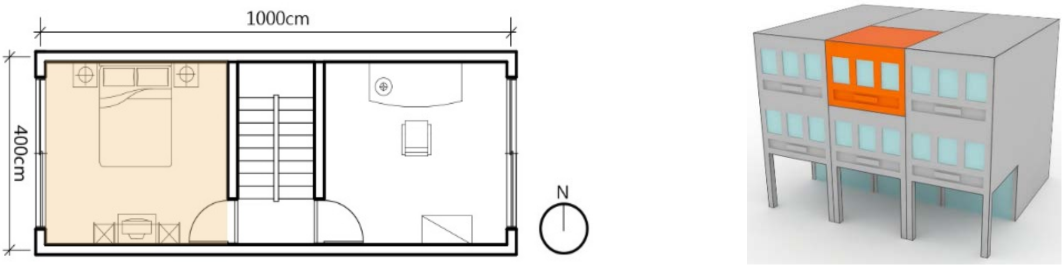


Figure1. Plan and model of simulated row-house

2.2 Weather data of simulation

In this study, two kinds of weather scenario were taken into account, which 1990~2012 local weather data with the format of TMY3 was used to simulate the current weather situation and the simulated future weather data by dynamical downscaling were applied for the simulation of the scenario 2030.

Taiwan, a small island with complex geographic region, is difficult and inaccurate to use global model for projecting future climate change in order to its coarse resolution. Lin et al.

(2015) carried out a dynamic downscaling simulation of Taiwan's climate for near future 2030. The WRF model was using the MAX Plank Institute Hamburg global model, ECHAM5/MPIOM. ECHAM5/MPIOM-WRF dynamic downscaling with 5 km resolution was used to discussed the impact of Taiwan weather condition under global warming. In this study, the future predicted hourly weather data, including dry-bulb temperature, humidity, wind velocity were provided by Lin et al.

2.3 Threshold of indoor temperature for risk evaluation

To evaluate risk of the emergency visits for cardiovascular disease associated with the indoor temperature, Lo et al. (2017) studied the relative risk in Taiwan, and the results showed that daily minimum temperature below 21°C in cold season (November to April) and daily maximum temperature above 30°C in hot season (May to October) were associated with an increase in hospital emergency visit rate of cardiovascular disease.

Table 1 Cardiovascular relative risk of indoor temperature

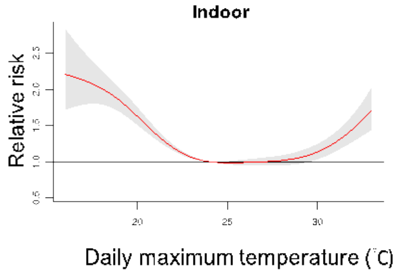
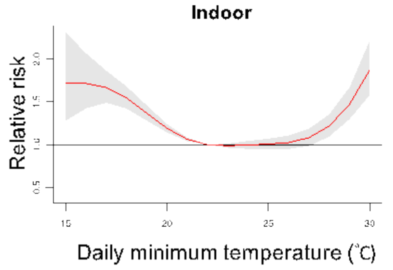
<table>
<tr><td rowspan="6">Daily maximum temperature</td><td>Temperature</td><td>CVD, RR (95%CI)</td><td rowspan="6">Daily minimum temperature</td><td>Temperature</td><td>CVD, RR (95%CI)</td></tr>
<tr><td>24°C</td><td>Reference</td><td>**19°C**</td><td>**1.366 (1.278 - 1.460)**</td></tr>
<tr><td>**30°C**</td><td>**1.134 (1.030 – 1.248)**</td><td>**20°C**</td><td>**1.190 (1.140 - 1.242)**</td></tr>
<tr><td>**31°C**</td><td>**1.268 (1.139 – 1.410)**</td><td>**21°C**</td><td>**1.061 (1.039 – 1.084)**</td></tr>
<tr><td>**32°C**</td><td>**1.459 (1.280 – 1.663)**</td><td>22°C</td><td>Reference</td></tr>
<tr><td colspan="2"> </td><td colspan="2"> </td></tr>
</table>

Table 2 Parameters of sensitivity analysis

	U value (W/m^{2}K)			Window		Shading (m)	Discharge Coefficient	
	T-1	T-2-1	T-2-2	T-3-1	T-3-2	T-4	T-5-1	T-5-2
Part	Roof	RC wall	Metal wall	SHGC	U value			
Original	1.08	3.16	3.16	0.87	5.9	0	0.4	0.4
Scenario	0.34	0.83	6.3	0.20	1.7	0.6	0.15	0.8

3. Research Result

To discuss the possibilities of row-house reforming to improve indoor thermal environment, sensitivity analysis was carried out to find out the design factors which sensitive to the number of days that inhabitants exposed in health risk. As shown in Table

2, sensitivity analysis was conducted according to the important building parameters in energy conservation regulations for building envelopes of residential buildings in Taiwan, including the U-value of roof, U-value of exterior wall, U-value of glazing, SHGC (Solar Heat Gain Coefficient), exterior shading devices of fenestration. In this study, WWR (Window-Wall Ratio) was not discussed due to reform restrictions on existing buildings. However, with the effect of ventilation, the ventilation performance of WWR was taken into account by changing the discharge coefficient of window.

The results of sensitivity analysis were shown in Table 3, which means the amount of change in risk days caused by every unit difference of each parameter. The results showed that discharge coefficient, solar heating gain coefficient, roof insulation and shading are more sensitive to adjust indoor temperature.

With the frequency of extreme event has gradually increased, indoor thermal environment that exposed in risk will obviously increases in the future. As shown in Table 5, sensitive design factors that derived from sensitivity analysis were combined as eight composite strategies to simulate the effect of reducing exposure risk by reformed strategies in 2030, and the result was compared to the original case in current weather situation. It is expected that strategies can still keep the number of risk days close to the current level and temporize the impact of climate change in 2030.

Figure 2 shows the simulation results of risk days that temperature exceed 30˚C in the hot season. Compared the number of risk days of T-0 in TMY3 (1990-2012) and 2030, 17.4% of risk days that exposed in overheat were increased in 2030. In addition, all of the reformed strategies were not allowed to reduce the exposed days close to T-0 in TMY3. However, all of the strategies were effective to reduce the number of risk days in hot season compared to T-0 in 2030. The effect of decreasing solar heat gain from double low-e glass (T-DG-1) can reduce 8.2% of risk days that exceed the threshold of 30˚C (RR above 13.4%), while increasing the discharge coefficient can reduce the 2.7% overheating days further.

The simulation results of risk days that temperature below 21˚C (RR above 6.1%) in the cold season are shown in Figure 3. Compared the number of risk days of T-0 in TMY3 and 2030, 17.4% of risk days that exposed in overcool were decreased in 2030. The result showed that improving discharge coefficient would increase 5.5% risk days in cold season. However, the discharge coefficient was the only one strategy that could be adjusted by human behavior. Furthermore, with the results of risk day of overcool and overheat, it is obviously shown that number of risk days in cold season was much more than the hot season in future Taiwan. Therefore, the increasing of discharge coefficient was proposed. In the days of overcooling, the discharge coefficient was decreased by reducing the effective open area to avoid the heat loss of indoor.

With the results of risk day in 2030, it is showed that if the temperature threshold is constant under future climate, the health risk will increase especially in the hot season. Hence, except the strategies of replacing 3mm clear glass to double low-e glass, increasing of discharge coefficient was also recommended to improve the effect of ventilation and reduce the heat that accumulated in the room.

Table 3 Result of townhouse sensitivity analysis

	Roof U value	Wall U value	SHGC	Glass U value	Shading	Discharge coefficient
Whole year	**-6.5**	2.7	**9.0**	-0.7	**5.0**	**12.3**
Hot season	**-7.7**	**2.7**	**19.4**	-1.0	0.0	**-27.7**
Cold season	1.3	0.0	**-10.4**	0.2	**5.0**	**40.0**

Table 4 Scenarios parameters of composite simulation

Scenario	Glass		Discharge Coefficient (-)	Roof U value (W/m^2K)	Shading (m)
	SHGC (-)	U value (W/m^2K)			
T-0	0.87	5.9	0.4	1.08	0
T-1	**0.28**	**2.6**	0.4	1.08	0
T-2				**0.36**	0
T-3				1.08	**0.6**
T-4				**036**	**0.6**
T-5			**0.62**	1.08	0
T-6				**0.36**	0
T-7				1.08	**0.6**
T-8				**0.36**	**0.6**

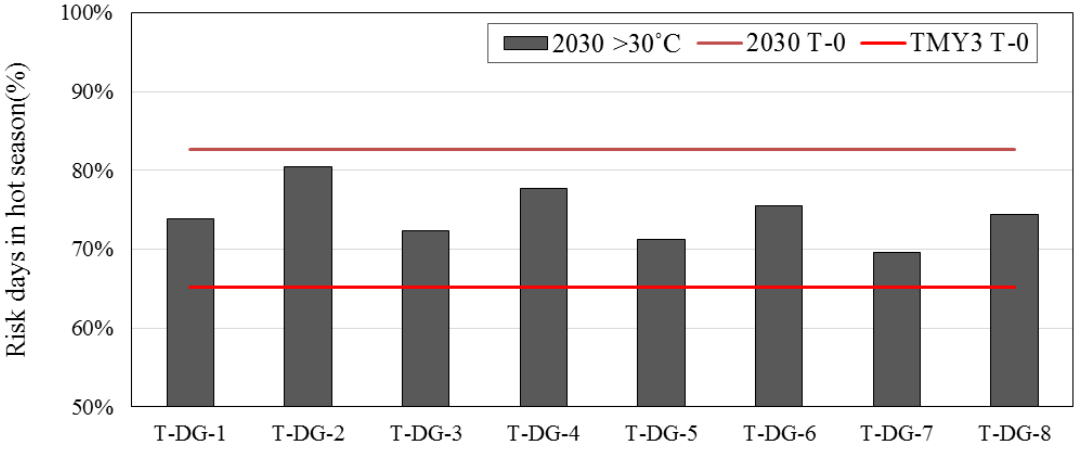


Figure 2 Percentage of overheat days in hot season in 2030

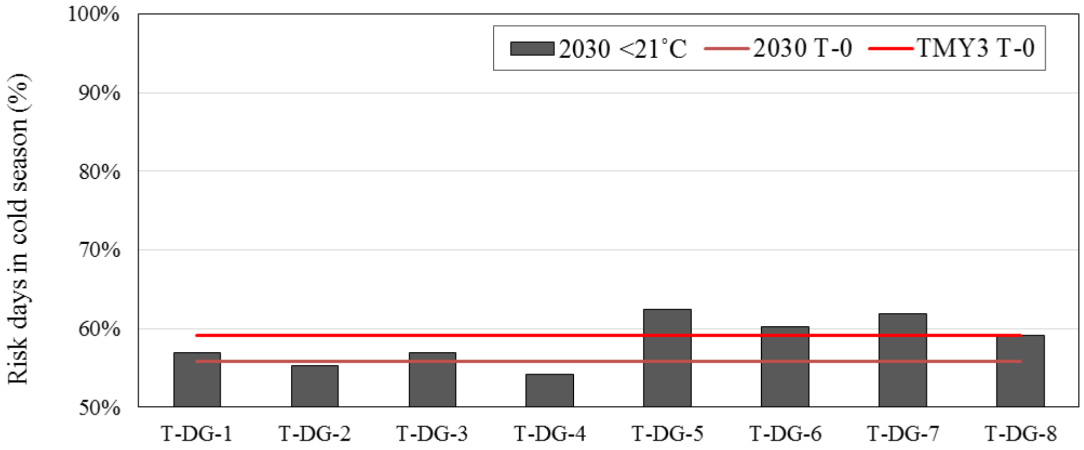


Figure 3 Percentage of overcool days in cold season in 2030

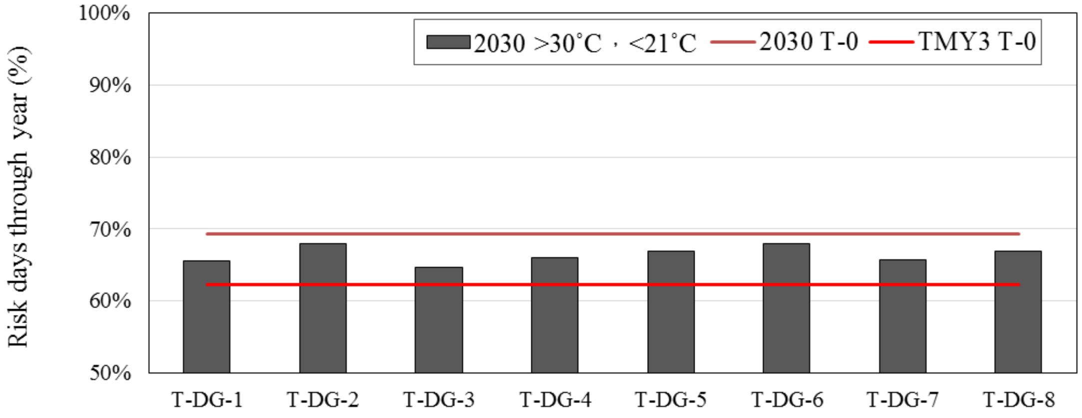


Figure 4 Percentage of risk days through whole year in 2030

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Wu P.C., Lin C.Y., Lung S.C., Guo H.R., Chou C.H. and Su H.J. (2011). Cardiovascular mortality during heat and cold events: determinants of regional vulnerability in Taiwan. Occupational and Environmental Medicine. 68, 525-530.

5. Published Paper etc.

1. Lin, C.H., Hsieh, Y.H., Zhang, W., Tsay, Y.S. (2018) Study on the Simulation Model of a Balcony Greenery System with Ventilation in a Hot and Humid Climate, ROOMVENT 2018, Espoo(Finland), Jun. 2-5, 2018.
3. Lu, M.C., Tsay, Y.S., Su, H.J., Hsu, N.Y., Lo, Y.C. (2018) Adaptation Strategies of Row-House to Climate Change in Taiwan, ROOMVENT 2018, Espoo(Finland), Jun. 2-5, 2018.
2. Lu, M.C., Tsay, Y.S., Hsu, N.Y., Su, H.J.(2017) Sensitivity Analysis of Building Constructions for Improving Adaptation to Climate, Healthy Building 2017 Asia, Sep. 2-5, 2017.

6. Research Group

1. Representative Researcher:
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2. Collaborate Researchers
1. Zhang, Weirong

6. Abstract (half page)

Housing Envelope Design for Adapting Heat Stress under Climate Change

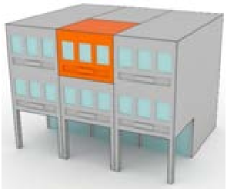
Yaw-Shyan Tsay (National Cheng-Kung University)

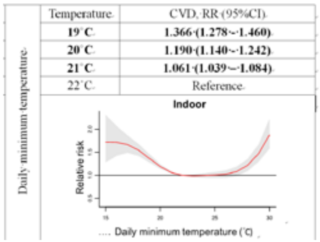
Summary

Under the concept of sustainable development, realizing the impact of climate on health risks and opportunities of adaptation and mitigation are important to protect humans from threats of dramatic climate change. Some researchers have found a significant relationship between temperature and health risk. Moreover, many researchers discussed the energy consumption and thermal comfort factors of the adaptation strategies, but the health risks were rarely considered for evaluation.

EnergyPlus was used to study the renovation strategies of a row-house. The indoor temperature threshold for seniors above 65 years of age who were suffering from cardiovascular disease was adopted to evaluate health risks. Furthermore, sensitivity analyses were carried out to select effective design strategies which will improve the health risks of indoor environments. Finally, the number of days exceeded the threshold was used to evaluate the benefit of various design strategies.

In scenarios where recent weather was taken into account, the results showed that the shading coefficient, insulation and ventilation performance played important roles in improving the adjustments to overheating and overcooling. In the scenario of 2030, which used dynamic downscaling weather data for its simulation, the results showed that ventilation control was an effective strategy to reducing these health risks.





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