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Considerations of Sustainable High-rise Building Design in Different Climate Zones of China

Kevin K. W. Wan[1], Man-Him Chan[1], and Vincent S. Y. Cheng[1†]

[1]Building Sustainability Group, Ove Arup & Partners Hong Kong Ltd, Level 3 Festival Walk 80 Tat Chee Avenue, Kowloon, Hong Kong SAR, China

Abstract

Buildings, energy and the environment are key issues that the building professions and energy policy makers have to address, especially in the context of sustainable development. With more tall buildings constructed in China, the impact on energy consumption and carbon emission would be great from buildings (2% increase of carbon dioxide annually between 1971 and 2004) . The imperative was to investigate the building energy performance of high-rise in different climate zones and identify the key design parameters that impose significantly influence on energy performance in sustainable building design. Design implications on glazing performance, sizing of the ventilation fans, renewable energy application on high-rise building design are addressed. Combination of effective sustainable building design strategies (e.g., building envelope improvement, daylight harvesting, advanced lighting design, displacement ventilation, chilled ceiling etc.) could contribute more than 25% of the total building energy consumption compared to the international building energy code.

Keywords: Sustainable design, High-rise building, Building energy performance, Climatic zones, China

1. Introduction

Since 1950s, cities continue to expand with increasing population worldwide. It is estimated that by year 2015, there will be 521 cities in the world that would hold a minimum of one million people (Johnson, 2008). It is also expected that more people will tend to move from rural locations to urban cities, which the ratio between urban population to rural population would be 3:2 in 2030 and 4:1 in 2050 (Ali et al., 2008). In order to hold the large population, more and more tall buildings are constructed. Only in 2006, 59 out of 100 tallest buildings in the globe are new (Oldfield et al., 2009). This is of true in China as it is reported that there will be a tall building upon completion every five days within the period from 2011 to 2013 (Foster. 2012). With more tall buildings constructed, the impact on energy consumption and carbon emission would be great from these building (2% increase of carbon dioxide annually between 1971 and 2004) (UNEP, 2007). However, one important issue that engineer needs to identify is that the climatic condition of the location (especially for China with more and more tall buildings to be constructed) where the tall building would determine the most effective strategy that the building should adopt to ensure true energy savings.

†Corresponding author: Vincent S. Y. Cheng
Tel: +852-2268-3684; Fax: +852-2268-3740
E-mail: vincent.cheng@arup.com

2. Approach of Sustainable Building Design

For sustainable building design, the most important is to define the base case as a reference to compare different energy saving strategies on a building. The Design standard for energy efficiency of public buildings GB50189-2005 (Ministry of Construction, 2005) is one of the most common standards adopted to carry out sustainable tall building design in China. In the energy analysis for tall buildings, energy consumption is broken down into different types, which are space cooling and heating, energy consumed in heat rejection with cooling tower, ventilation fans, pumps & auxiliary, miscellaneous equipments and area lightings. The breakdown of energy consumption allows designers to understand design characteristics over different locations with different climatic conditions. With this in mind, it is possible to identify the key design criteria that would help to reduce energy consumption for tall buildings.

Office building development is one of the fastest growing areas in the building sector especially in major cities such as Beijing and Shanghai. On a per unit floor area basis, energy use in large office building development with full air-conditioning can be 70~300 kWh/m^2, 10~20 times that in residential buildings (Jiang, 2005; Jiang, 2006). Figure 1 shows the framework of sustainable design strategies for offices. When energy savings strategies are selected based on the building characteristics, consideration shall be on if whether the selected strategies is sustainable to be implemented into the building in res-

pect to lower energy consumption, protection of human health and reduction in waste and pollutant generation. In sustainable green building design, strategies for energy savings are separated into three groups:

- Passive Design Strategy - "series of architectural design strategies used by the design" to allow buildings to be able to respond to the changes in climate (Kroner, 1997).
- Active Design Strategy - "elements through which buildings self-adjusted" with the changes within the building due to internal activities and changes in external climate (Wigginton et al., 2002).
- Renewable Design Strategy - energy that does not have negative impacts with zero emission on the environment over the complete life cycle and is recyclable in nature (Chen, 2003; Tester et al., 2005).

3. Climatic Conditions

China is a large country with an area of about 9.6 million km^2. About 98% of the land area stretches between a latitude of 20~50°N, from the subtropical zones in the south to the temperate zones (including warm temperate and cool temperate) in the north (Zhao, 1986). The maximum solar altitudes vary a great deal, and there is a large diversity in climates, especially the temperature distributions during winters. China is situated between Eurasia, the largest continent and the Pacific Ocean, allowing the monsoons to be well developed. The monsoon climate, therefore, tends to be dominant, with a marked change of wind direction between winter and summer, as well as seasonal variation of precipitation according to whether the maritime monsoon advances or retreats. Besides, characteristics associated with continental climates can be identified, with warmer summer, cooler winter and a larger annual temperature range than other parts of the world with similar latitudes. China also has a complex topography ranging from mountainous regions to flat plains. These diversities and complexities have led to many different regions with distinct climatic features. In terms of the thermal design of buildings, there are five major climates, namely severe cold, cold, hot summer and cold winter, mild, and hot summer and warm winter (Ministry of Construction, 1993). This simple climate classification is concerned mainly with conduction heat gain/loss and the corresponding thermal insulation issues. The zoning criteria are mainly based on the average temperatures in the coldest and hottest months of the year. The numbers of days that the daily average temperature is below 5°C or above 25°C are counted as the complementary indices for determining the zones. Figure 2 shows an overall layout of the five major climates. Because of the varying topology and, hence, elevations, there are nine regions - both the severe cold and cold climates have three sub-zones.

With vast knowledge on the importance of three groups of energy strategies, another critical point is to have a great understanding on the climatic conditions. In this paper, four types of climatic conditions are included based on the climatic zone of China, which are severe cold, cold, hot summer & cold winter and hot summer & warm winter. The reason for selecting these climatic zones is because the growing cities are located near the coast in the east of China. As there are four different climatic conditions, strategies adopted for tall buildings at different locations would vary. For example, free-cooling may possibly be used for a short period of time in Southern China, yet in contrast, more often in the Northern China under cold weather condition.

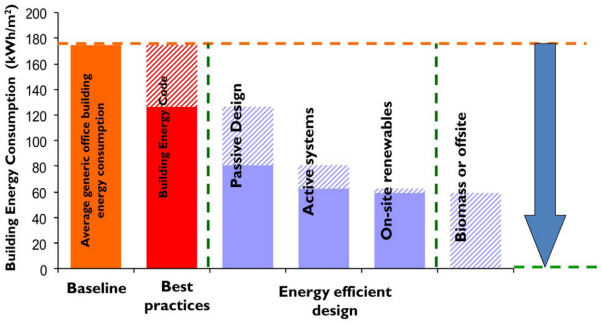


Figure 1. Framework to sustainable design strategies.

4. Building Energy Simulations

4.1. Hourly weather data

A total four cities within the major climatic zones was selected for the analysis (Fig. 3). These were Shenyang (severe cold), Beijing (cold), Shanghai (hot summer and cold winter) and Shenzhen (hot summer and warm winter). Building energy simulation was conducted using the simulation tool DOE-2 (DOE-2 supplement, ver. 2.1E, LBL-34947, 1993). Two major inputs were developed for each

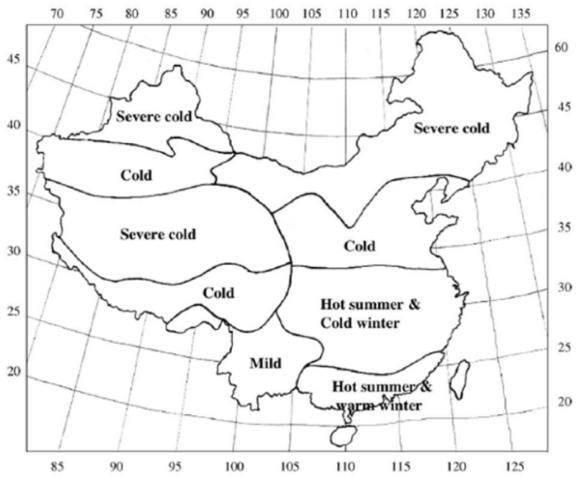


Figure 2. Geographical distribution of the major climate zones in China (Ministry of Construction, 1993).



Figure 3. Building energy simulations in 4 different climates across China.

of the four cities °V hourly weather databases and generic office building designs. The Typical Meteorological Year (TMY) method, developed by the Sandia National Laboratories in the United States is one of the most widely adopted methods for determination of typical weather years (Hall et al., 1978). A TMY consists of twelve typical meteorological months (TMMs) selected from various calendar months in a multi-year weather database. An 8,760 hourly TMY weather file was used for each city to represent the prevailing climatic characterises.

4.2. Generic office buildings

A base case office building was developed to serve as a baseline reference for comparative energy studies. The base case was a 35 m × 35 m, 40 storey building with curtain walling design, 3.4 m floor to floor height and 40% window to wall ratio (as shown in). The total gross floor area is 49,000 m^2 (41,160 m^2 air conditioned and 7,840 m^2 non-air conditioned). The air conditioned space had five zones - four at the perimeter and one interior with an occupancy density of 68 m^2/person, a lighting load density of 15 W/m^2 and an equipment load density of 18 W/m^2. The indoor design conditions were 26°C with 40~65% relative humidity in the summer and 20°C during winter. Infiltration rate was set at 0.45 air changes per hour throughout the year. The building and its lighting system operated on an 11 h day (07:00~18:00) and five-day week basis. Obviously, each city would have rather different building envelope design to suit the local climates. For instance, heat loss is a key design consideration in Shenyang, and as such, walls and roofs tend to have substantial thermal insulation. In subtropical climates, however, office buildings are cooling dominated, where solar heat gain is by far the largest component of the building envelope cooling load. Thermal insulation to the external walls is, therefore, less important. The Design Standard for Energy Efficiency of Public Buildings 2005 (Ministry of Construction, 2005) was used to develop generic building envelope designs that would meet the minimum requirements in the thermal designs for the four cities on the mainland. Table 1 to Table 3 are the design assumptions and the design criteria used for the energy simulation for a commercial building under different locations. The HVAC system was developed based on the local design code for HVAC (Ministry of Construction, 2003). Briey, the system was a four pipe fan coil type with winter and summer set point temperatures of 20°C and 25°C, respectively, for all four cities. Chilled water was provided by water cooled centrifugal chillers with a coefficient of performance of 4.7 (heat rejection through cooling towers), and space heating was provided from natural gas fired hot water boilers with a thermal efficiency of 89%. The same system type was used for all four cities but with different sizes according to the individual system peak cooling and heating loads.

A total of four simulations have been carried out in four cities of different climatic conditions. In order to realize the building characteristic with respect to energy consumption at different locations, simulation would be required to identify the energy consumption characteristics of a typical high-rise building under different climatic

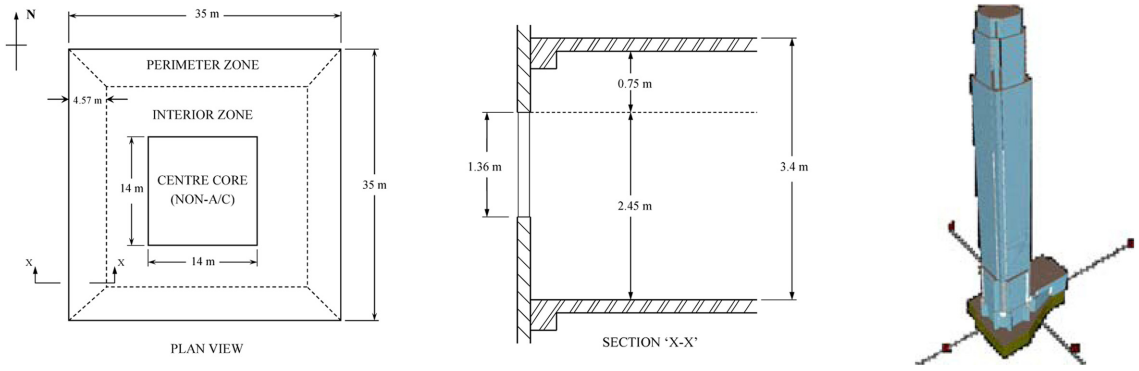


Figure 4. Generic office base case model.

Table 1. Summary of key building envelope design parameters (Ministry of Construction, 2005; Ministry of Construction, 2003)

City	Climates	Building element	U-value (W/m^2 K)	Shading coefficient	
				North	Other orientations
Shenyang	Severe cold	Wall	0.44	-	-
		Window	2.50	0.64	0.64
		Roof	0.35	-	-
Beijing	Cold	Wall	0.60	-	-
		Window	2.60	0.7	0.7
		Roof	0.55	-	-
Shanghai	Hot summer and cold winter	Wall	1.00	-	-
		Window	3.00	0.6	0.5
		Roof	0.70	-	-
Shenzhen	Hot summer and warm winter	Wall	2.01	-	-
		Window	5.60	0.4	0.4
		Roof	0.54	-	-

Table 2. Indoor design condition and internal load density assumptions for buildings in different climate zones (Ministry of Construction, 2005)

Location	Indoor design condition		Internal load density		
	Summer (°C)	Winter (°C)	Occupancy (m^2/person)	Lighting (W/m^2)	Equipment (W/m^2)
Shenyang, Beijing, Shanghai, Shenzhen	25	20	8	15	18

Table 3. Heating, Ventilating and Air-conditioning (HVAC) System used for the buildings in different climate zones (Ministry of Construction, 2005)

Location	HVAC		
	AHU	Cooling	Heating
Shenyang, Beijing, Shanghai, Shenzhen	Four-pipe fan coil	Centrifugal chiller (Water-cooled, COP=4.7)	Gas-fired boiler

conditions based on the climatic zone of China as shown in Fig. 4. With the use of advance computation simulation with the acquired weather data of these locations, energy simulations are carried out, which shows the energy breakdowns of a commercial building under different climatic conditions.

5. Building Energy Performance in Different Climate Zones

5.1. Building loads performance

Building heating and cooling load breakdown is carried out for the high-rise building under different locations, which the additional energy required in cooling and heating to achieve the designed indoor environmental condition due to the standard façade design of a high-rise building at different locations of China is as shown in Table 4.

As can be seen in , it can be found that glazing has the highest influences on the energy consumption within high-rise building. Beyond that, it is obvious to be seen that the window conductivity has a higher impact in the

Table 4. Annual heat gain/loss (MWh) in four different climates of China

Building Envelope Components	Building loads	Shenyang	Beijing	Shanghai	Shenzhen
Window Conduction	Heating	-1901.6	-973.9	-791.8	-919.8
	Cooling	-924.9	-715.1	-441.7	-813.7
Window Solar Heat	Heating	513.3	374.8	259.2	319.5
	Cooling	2352.4	2967.7	1979.7	1927.1
Wall Conduction	Heating	-523.5	-347.4	-388.4	-579.6
	Cooling	-118.9	-17.8	114.1	7.3
Roof Conduction	Heating	-40.8	-35.8	-29.7	-41.9
	Cooling	-6.2	8.0	16.6	17.3

*Negative sign for heat loss

northern region than in the southern region. In contrast, it seems that the northern region of China would have a stronger solar heat gain than in the southern region possibly due to the sun location where the sun is located at a lower position in the north (Shenyang and Beijing) compared to the center and southern region of China (Shanghai and Shenzhen).

5.2. Building energy consumption characteristics

By using the design criteria as provided, building energy simulations are then carried out with the results as shown from Figs. 5 to 8.

Annual total building energy consumption was 7565, 6637, 6450 and 6476 MWh in Shenyang, Beijing, Shanghai and Shenzhen, respectively. Annual energy use per unit gross floor area varied from 157 kWh/m^2 in Shenzhen to 184 kWh/m^2 in Shenyang. These were well within the current energy use range of 70~300 kWh/m^2 in large scale commercial buildings with centralised HVAC systems. Total annual building energy consumption was split into weather sensitive (HVAC) and non-weather sensitive (lighting and equipment) components. HVAC annual energy use varied from just under 2,700 MWh in Shenzhen to about 4,600 MWh in Shenyang. The main difference is in the amount of energy use for winter heating, 1,925 MWh in Shenyang compared with 70 MWh in Shenzhen. The annual energy use for cooling in Shenzhen was more than twice that in Shenyang, but because of its short, mild winter, the HVAC total was still 13% less than that in Shenyang. It was found that HVAC auxiliary (i.e., fans and pumps) accounted for a significant proportion of the HVAC total, ranging from 35% in Shenyang to about half that in Shenzhen. Incorporating variable speed fans and pumps to cater for the part load conditions could offer great energy savings potential. As can be seen from these figures, it is found that the northern region would rely more on heating system and the southern region would rely more on cooling system to maintain the satisfactory level of the indoor artificial environmental condition.

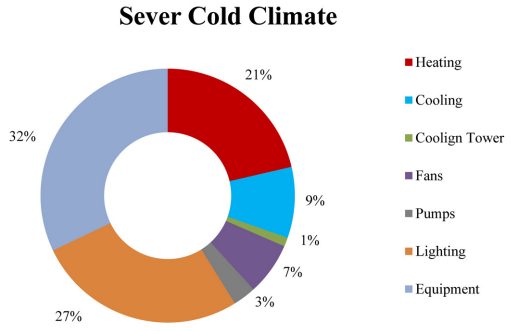


Figure 5. Energy breakdown for a commercial building (Severe Cold).

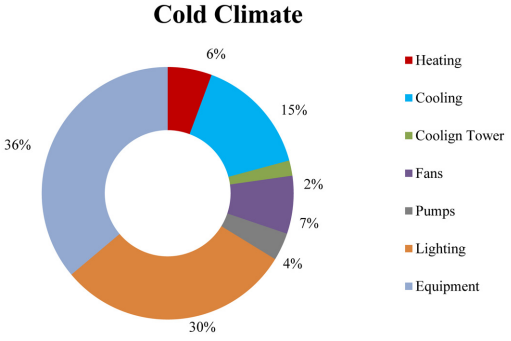


Figure 6. Energy breakdown for a commercial building (Cold).

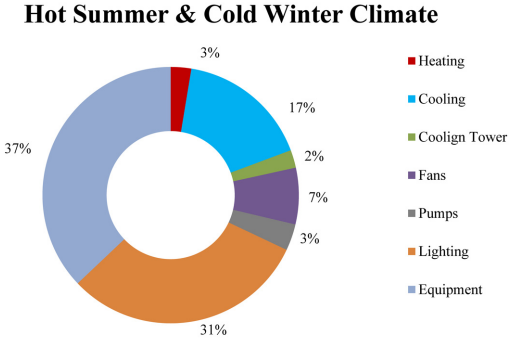


Figure 7. Energy breakdown for a commercial building (Hot summer & cold winter).

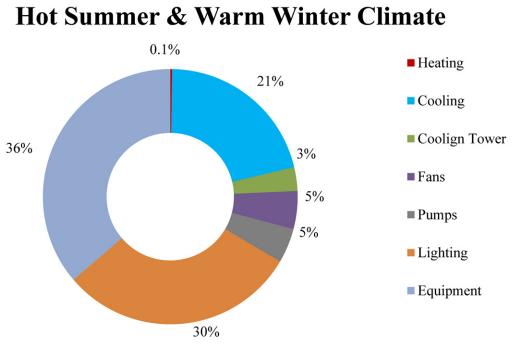


Figure 8. Energy breakdown for a commercial building (Hot summer & water winter).

6. Considerations of Design Impact on High-rise Building Design

6.1. Impact of passive design - glazing

After identifying glazing as the major contributor to energy consumption, further analysis is identified the opportunities for energy savings by carrying out an analysis with two major properties of glazing, which are U-value (representing the thermal conductivity, W/m^2) and SC (Shading Coefficient) value (representing the solar heat gain). The results are as shown in Figs. 9 and 10.

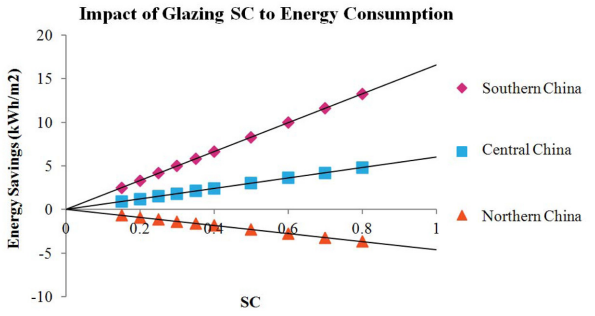


Figure 9. Impact of glazing SC to Energy Consumption in a high-rise building.

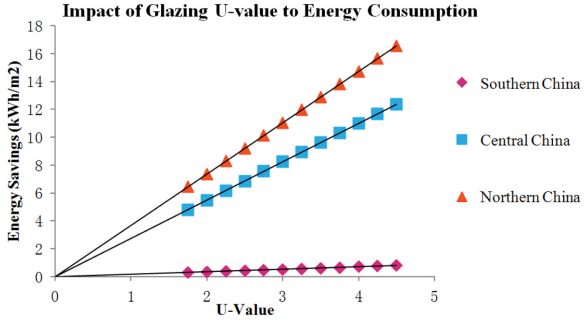


Figure 10. Impact of glazing U-value to Energy Consumption in a high-rise building.

It is found that high-rise building that SC value of glazing plays an important role in the south (Wan et al., 2010). This is because the HVAC system in the Southern China is focused on cooling, and the solar heat gain penetrated through the glazing would contribute to additional energy in cooling in order to achieve the required indoor environmental condition. Therefore, buildings in the Southern China would rely on glazing with low SC in order to reduce solar heat gain in order to reduce energy consumed in cooling. In contrast, Northern China should adopt glazing with high SC in order to harvest the solar energy to reduce the energy consumption in heating.

However, high-rise buildings in Northern China should use glazing with low U-value in order to trap the heat from escaping the indoor environment as there is a huge temperature (> 30°C) difference between the indoor and outdoor environment (Shenyang Beijing winter could have temperature reach to −38.0°C and −27.4°C respectively). In contrast, U-value for buildings in Southern China would not be as significant as the temperature difference between indoor and outdoor air temperature would seldom exceeds more than 15°C.

6.1. Impact of active system - hvac system & lightings

6.1.1. HVAC system

It is obvious that energy savings of cooling is more effective in Southern China and energy savings of heating is more effective in Northern China due to the difference in climatic condition. Due to this reason, energy consumption in ventilation fans could be overlooked by designers. It is found in the previous study that by adopting air side heat recovery, energy saving of 1% can be achieved in Southern China and energy saving of 4% can be achieved in Northern China (Cheng et al., 2011). In this analysis, it is found that the proportion of energy saved in ventilation fans is actually much larger than expected, especially in Southern China where energy consumption can be reduced by 12%, while only by 8% in Northern China. This finding suggests that the efficiency of the HVAC equipments and the adoption of natural resources are extremely important in order to reduce the energy consumption in tall buildings.

6.1.2. Area lightings

In general, tall buildings are usually occupied during daytime and by implementing stringent control, much energy saving can be achieved. This can be undertaken by adopting lighting system with dimming control. According to Tung (TNT Lam, 2008), dimming control can be separated into three types, a high frequency dimming control, continuous/off control and stepped dimming control. With the appropriate selection of the dimming control system, energy saving opportunities can be achieved as shown in Fig. 9. Internal heat loads (i.e., occupants, lighting and equipment) accounts for 75% of the total building annual cooling load. More energy efficient lighting designs and office equipment would help reduce the elec-

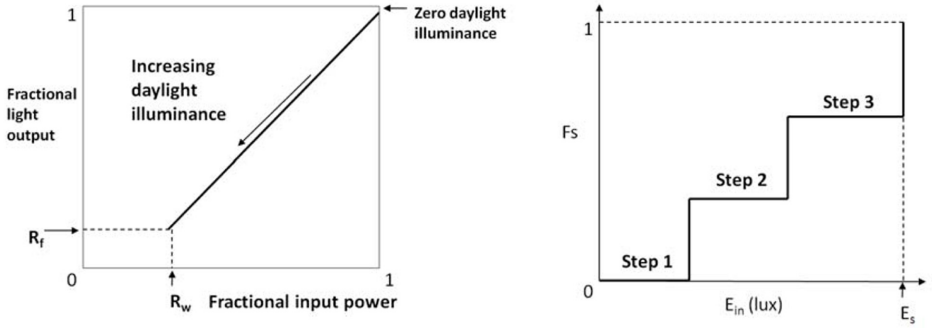


Figure 11. Energy savings for high frequency dimming control (left) and stepped dimming control (right) (TNT Lam, 2008).

tricity use for not only the lighting installations and electric appliances but also for the cooling plant and should be promoted, although contributions to lowering the heating requirement would be affected, particularly in severe cold and cold climates. This should certainly be a priority area in any energy efficiency programme for fully air conditioned office buildings in warmer climates.

6.2. Impact of renewable energy

As technology advances, more and more renewable energy could be adopted. For example, some of the most common approaches is solar hot water system and photovoltaic system to maximize the utilization of available solar heat on-site. Biodiesel is also another approach that could be used as a renewable fuel for tri-generation, such as the first zero carbon building, Construction Industry Council (CIC) Building, in Hong Kong that replaces conventional fossil fuel with biodiesel from waste cooking oil to generate electricity. Waste cooking oil is used as the carbon emission of this type of biodiesel fuel would emit much less carbon compared to the conventional fossil fuel, and avoid the generation of methane gas at landfills (waste cooking oil is usually sent to landfill). With the adoption of these renewable energy system, carbon emission of commercial buildings could be reduced and improve the global environment. With the vast experience and findings from energy analysis for the same tall buildings over different climatic zone, it would be easy to identify the best energy saving strategies for tall buildings during design stage, and thus enhance the efficiency and effectiveness of tall buildings during their lifetime regardless of where they are. The next section would show four examples of tall buildings located at each of the climatic zones and what strategy is used to response to the local climatic condition.

7. Effective Sustainable Buildings Designs

The implementation of the building energy codes and the green building design guideline in the market has encouraged the adoption of energy-efficient designs and renewable energy for building design. Green and sustainable buildings are now a key consideration in new building developments and carbon reduction in China (Cheng et al., 2007). With the opportunities of many tall building constructions, vast experiences are collected to design buildings that would adapt to the climatic condition under different location of China. Four sustainable case studies from our project experience in four different climatic zones in China are selected to show the responsiveness of these buildings to the local climatic condition.

7.1. Shenyang (Severe cold)

In order to cater for the high temperature difference between indoor and outdoor environment, high performance building envelope is adopted with the glazing U-value of 1.80 W/m^{2}K, almost half of that to the base case with U-value of 3.24 W/m^{2}K. This would reduce heat loss from the indoor environment to the outdoor environment, resulting with less energy consumption in the cooling system. Another interesting idea is to reduce the water inlet temperature for the condensing water loop. Typically, the condensing water loop would circulating in between 32^{o}C (condensing water inlet) and 37^{o}C (condensing water outlet) for good chiller performance. However, with the severe cold climatic condition, the condensing water loop temperature would be re-adjusted to operate between 29^{o}C and 34.6^{o}C. By readjusting the condensing water temperature, there is less energy required to heat the water joining the condensing water loop, and that the chiller would actually operates at a relatively higher COP compared to the typi-



Figure 12. Sustainable buildings design in different climate zones in China.

cal condensing water loop temperature range.

7.2. Beijing (Cold)

Similar to the building in Shenyang, there is a large temperature difference between the indoor and outdoor environment in Beijing with the temperature difference that could reach up to 40°C when under extreme cold winter (–20°C). With this in mind, glazing with low U-value is selected in order to optimize the building envelope to lower heat loss from indoor environment to outdoor environment to reduce energy consumption in heating. Occupancy sensors are located in order to allow dimming system to operate in building. The building also adopts demand control ventilation to reduce energy consumption in the air-conditioning system. Furthermore, in order to harvest more solar energy, photovoltaic and solar hot water systems are adopted to maximise the use of solar energy available on-site.

7.3. Shanghai (Hot Summer & Cold Winter)

Shanghai climatic condition is slightly different from the Northern China, where the temperature difference between the indoor and outdoor environment is not as much compared to the climatic zone at Northern China. However, as there is hot summer and cold winter, the building would adopt cooling and heating to ensure a comfortable indoor environmental condition can be achieved. Therefore, both the U-value and the Shading Coefficient of the glazing is reduced to optimize the façade design (Lam et al., 2008). In addition, occupancy control is adopted to reduce energy wastage on both the air-conditioning system and the artificial lighting system to maintain low energy consumption while still able to achieve a comfortable indoor environment for building occupants.

7.4. Shenzhen (Hot Summer & Warm Winter)

Shenzhen is located within the hottest zone out of the four zones, which mainly focuses on cooling system to provide a comfortable indoor environment for building occupants. With this respect, highly efficient glazing is selected (glazing with low SC) to reduce the cooling load by minimizing solar heat gain. Furthermore, lightings with low power density (LPD) are used to reduce electricity consumption in artificial lighting system. This would also reduce the amount of heat generated by the artificial system, thus further reducing energy required for cooling purpose.

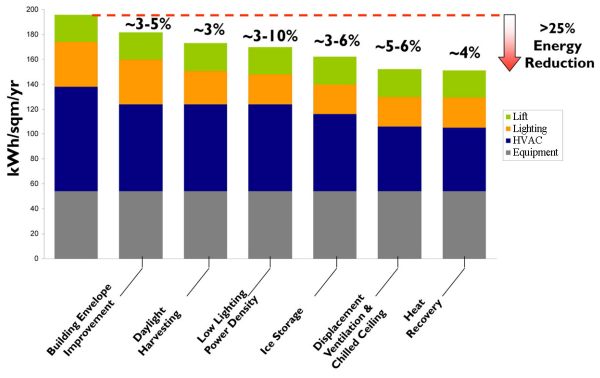


Figure 13. Consideration of energy-efficient building design strategies.

7.5. Lessons from sustainable building project in different climates

Various advanced building design technologies have been adopted in our sustainable building project experience in different climates. Contribution of the energy saving from various sustainable design strategies could be varied from location to location due mainly to the climatic influence and other design consideration (Fig. 13). Reduction of the cooling load and heating load via the improvement of the building envelope could have significant variation of the building energy improvement between cold and the sub-tropical climates, with contribution of 2~8% of the energy reduction. The daylight harvesting design, generally could contribute about 3% of the total energy saving, would be very much depends on the building window-to-wall ratio and the selection of the glazing in the actual architectural design. In additional, the design of the electrical wiring and the incorporation of the daylight sensors would determine the ultimate daylight control and this is necessary to work close with the electrical designer in the sustainable design consideration. Lower lighting power density could contribute significant energy saving in various types of the building project, varied from 3 to 10% depending of the intensity of the implementation. Reduction of the lighting power density would not only reduction the electrical energy contribution but less heat dissipation to the surrounding and thus reduce the cooling load demand and cooling energy consumption at the same time. Implementation of the ice storage could contribute 3~6% of the energy saving in different climates. The Ice storage system could make use of the peak/off-peak electricity tariff scheme to provide cooling storage during off-peak time and reduce the overall operation cost. Chilled water or ice can be produced to charge up the chilled water tank or ice tank during the off-peak time (e.g., night time) and the electricity price could be as low as 30~50% of peak hour. The displacement ventilation and chilled ceiling designs make use of similar principle to reduce the required fan power supply. The system can provide a better indoor air quality and thermal comfort compared with the traditional conditioned air supply. The energy consumption benefit from the system saving due to relative higher supply air temperature (16~18°C) and lower fan power (benefit from utilizing the air buoyancy). Air-side heat recovery can recover cooling/heating energy from exhaust air to reduce the cooling/heating fresh air load in the areas when a large amount of fresh air requirement. A air recovery ventilator or known as heat exchanger would induce a counter-

flow between the inbound and outbound air streams and could contribute about 4% of the energy saving. Combination of the efficient sustainable building design strategies could contribute more than 25% of the total building energy consumption international building energy code of China. Although this study focused on the major climates across China, it is envisaged that the approach and analysis could be applied to other locations with similar or different climates.

8. Conclusions

As urban population continues to grow, more and more buildings are constructed. This indicates that more energy would be consumed, and there will be a growing demand for more energy use. This would put more pressure on the already over-stretched electrical power supply systems, though the overall impact on total primary energy requirement could be either positive or negative depending on whether savings in space heating could out-weight increases in cooling. Advanced energy saving strategies to ensure more energy could be saved and ensuring buildings are operating effectively and efficiently are crucial in the current sustainable building market. However, there is no universal energy saving strategies, and would require largely determined by the climatic condition.

In this paper, four zones of China have been selected with case studies and simulation to discuss the impact on passive design, active system and renewable system. The four buildings are located in severe cold region (Shenyang), cold region (Beijing), hot summer and cold winter region (Shanghai) and hot summer and warm winter region (Shenzhen). The case study and the energy simulation illustrate the difference in energy savings percentage of different energy saving approach under different locations. For example, glazing U-value is recommended to be as low as possible in Northern China to reduce heat loss, while not as effective in Southern China. In contrast, glazing SC would have the opposite impact, which should be low in Southern China to reduce solar heat penetration while the effect is very little in Northern China. It is also found that the proportion of energy saved in ventilation fans is actually much larger than expected, especially in Southern China where energy consumption can be reduced by 12%, where energy consumption on cooling can only be reduced by 8%. The HVAC equipments and the adoption of natural resources are extremely important in order to reduce energy consumption in tall buildings. Renewable energy is another key design consideration in sustainable high-rise building design. Contribution of the energy saving from various sustainable design strategies could be varied from location to location due mainly to the climatic influence and other design consideration. Combination of effective sustainable building design strategies could contribute more than 25% of the total building energy consumption international building energy code.

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