

Sustainable tall building and Vertical compact city

Sung Woo Shin

Sustainable Building Research Center, Hanyang University, Korea
swshin@hanyang.ac.kr

ABSTRACT: From the 20th century, Eco cities have emerged in neighboring large cities in order to protect the environment and cities have been designed to use eco-friendly energies. But this Urban sprawl gave rise to inefficiency of land use and exponential energy consumption, thereby resulting in not only environmental degradation but also social disconnection of communication and dialogue. Thus, the direction of cities in the 21st century is reset toward Compact city and this has developed into a very concrete concept of Sustainable Compact City. This compact city avoids external sprawl. This Sustainable Compact City is ultimately designed to 1) reduce urban energy consumption to combat global warming and 2) revive traditional large cities by reducing suburbanization.

1 THE DEVELOPMENT OF CITY STRUCTURE

1.1 *The growth and environmental problems of cities*

The development of modern industrial society and cities has been made in a full swing after the industrial revolution which took place in most of the western developed nations. Due to this development, the conventional agrarian society has transformed into industrial cities. During this transition, cities grew at a faster pace as much population moved to new industrial regions and cities have been covered with concrete buildings and asphalt roads as a result of the increase in traffic between cities. This development of industrial society and urbanization has led to subsequent economic growth and the development of materialistic social specialization, but at the same time urban society has engendered lots of problems.

While growth-driven cities become huge, much population has concentrated on limited areas because city growth has its own limits. Accordingly, the problem regarding the supply of houses for accommodation has arisen and the quality of the air and water has become poorer due to industrial activities. In addition, air pollution has deteriorated due to the greenhouse effects from the development of the existing Greenfield. In other words, while modern cities made use of more fuels and energy sources to produce more goods and make people consume more, there was more environmental degradation and more natural resources were depleted. Furthermore, during the process of production and consumption, more wastes were released, damaging urban environment significantly (Ng, 2010).

1.2 *Eco City for addressing urban problems*

The most serious one out of urban problems is environmental pollution. That's because pollution is the most fundamental problem posing a grave threat to not only cities and one nation but also the earth, the living place for mankind. Thus, poor environment in large cities has been seen around satellite cities surrounding large cities such as Fig.1(a). This has led to horizontal

expansion of another city like heat islands. So, from the 20th century, Eco cities have emerged in neighboring large cities in order to protect the environment and cities have been designed to use eco-friendly energies so that cities don't release pollutants and less carbon dioxide, the culprit of the global warming, is emitted. (Fig.1(b)). However, lots of construction costs were spent for electricity and the development of roads, water supply and drainage system so as to maintain these eco cities. Besides, transportation burden was created for the purpose of connection between eco cities and large cities such as logistics, hospitals and schools. This was related to demand for excessive energy and imposed more burden on the environment. Urban sprawl gave rise to inefficiency of land use and exponential energy consumption, thereby resulting in not only environmental degradation but also social disconnection of communication and dialogue. It means cities could no longer become sustainable ones (Shin, 2012)

The concept of sustainable cities is not merely related to the environment in light of city development or harmonization of development and the environment. Rather, it is an attempt to draw the attention toward the environment and development for a better quality of living for the current and the next generation. Thus sustainable cities define sustainable urban behavior to enhance quality of human living with reducing environmental load as shown in Fig. 2. This is based on the spirit of UN Conference on Environment and Development held in Rio, Brazil, 1992 (UNCED, 1992).

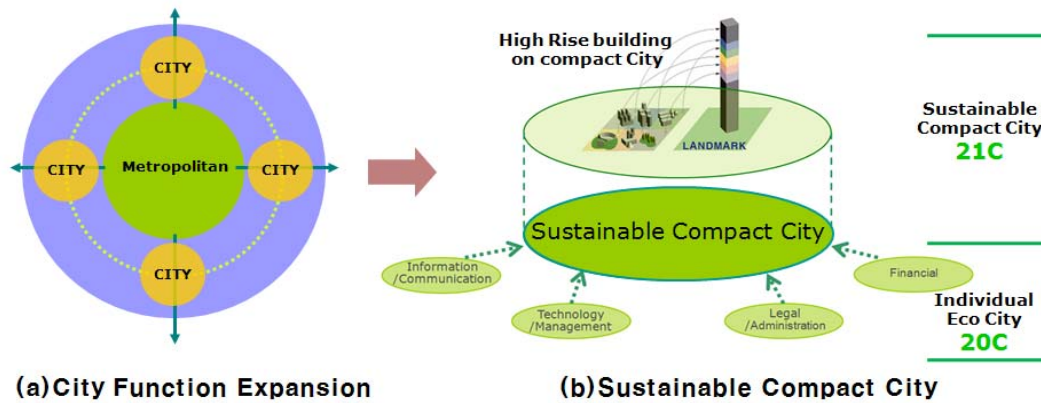


Figure 1. City Development Process (CTBUH, 2013)



Figure 2 Sustainable urban design concept

1.3 Sustainable Compact City

Thus, the direction of cities in the 21th century is reset toward Compact city and this has developed into a very concrete concept of Sustainable Compact City(see Fig.3.). The concept of “sustainable” means that as shown in Table 1, a city value structure for sustainable environment in the next generation focuses on the earth’s environment from previous efficiency, the development of compact city from previous facility-oriented urban structure. Among them, Compact city avoids external sprawl. Instead, it builds super tall buildings in urban areas where life infrastructure such as public transportation is well in place, reducing social costs and upgrading liv-

ing standards. (see Fig.1(b)) This kind of development model comes from the United States' large cities and has been recognized as the most feasible alternative in city development. The center in cities is packed with super tall buildings and 50% out of the rest of the area is green zone where ecological pillar is set, which is the characteristics of Sustainable Compact City as shown in Table 2.



Figure 3 City Concept Transition

Table 1. The Change in Urban Space Structure in the 21th Century

구 분	City In the past	Future sustainable compact city
Urban space structure	single-functional city	multi-functional city
	two-dimensional (horizontal) expansion - driven city development (growth first)	Three dimensional (vertical) network type focusing on environmental capacity (qualitative improvement)
	single-functional space	complex, multi-functional space
	Workplace-Residence Separation	closeness between workplace and residence, function composition, enhanced convenience
	facility-oriented city development	compact city establishment
	centralized metropolitan transportation system	Radiantly circulating transportation system

Table 2. Characteristics of Sustainable Compact city

Urban density	Urban concentration, decentralized concentration, high-density architecture
Land use	Land use for multiple purposes, Green zone and open space, Closeness between workplace and residence, (High Land Intensity)
Transportation	Easy access to public transportation Low usage of vehicles.
Social effect	Improved fairness, Living closer together offers the advantages of urban life, Social vitality, Open space and view
Economic effect	Self-sufficient, Cost effective infrastructure, Less Life Cycle Cost (LCC)
Environmental effect	Lower environmental degradation, Energy conservation

This Sustainable Compact City is ultimately designed to 1) reduce urban energy consumption to combat global warming and 2) revive traditional large cities by reducing suburbanization (IBEC, 2002).

For sustainable compact city, super tall buildings are considered as the best solution because as shown in Fig.1(b), super tall buildings can concentrate numerous functions of the city into one area, which is the strong point. Namely, super tall building improves land use efficiency in urban centers and encourages eco-friendly land use by securing open space and public space for pedestrians within the city. Plus, super tall building plays a vital role in creating energy and resource-conservative urban structure by closely connecting workplaces and residence through public transportation.

2 THE ADVANCEMENT OF SUPER TALL BUILDING.

- The shift of locations of super tall buildings; from North America to Asia
- The shift in terms of building use; office to mixed and other uses such as residential
- The shift in terms of principal structural materials; from all steel structures to composite or RC structures

As shown in Table 3 Super tall building has been in fashion on three occasions so far. The first was in 1930 when empire state building was constructed. The second was in the 1970s when World Trade Center and Sears Tower were built. Finally Burj Khalifa was constructed in 2010, Dubai. As shown in Fig.4, in super tall buildings, the height has been increasing for the past 12-13 years since 2000 and four ultra super tall buildings whose height exceeds 1,000m are under construction.

Table 3 (part 1). 2013 World Scyscrappers (SimArt, 2013)

Building name	Rank	Location	Floors	Hight (m)	Year Completed
Burj Khalifa	1	Dubai	163	828	2010
Shanghai Tower	2	Shanghai	121	632	2014
Makkah Clock Royal Tower [Abraj Al Bait]	3	Makkah	120	601	2012
Ona World Trade Center [New World Trade Center]	4	New York City	104	541	2013
Taipei 101	5	Taipei	101	509	2004
Shanghai World Financial Center	6	Shanghai	101	492	2008
International Commerce Centre [Union Square]	7	Hong Kong	118	484	2010
Petronas Tower 1 [Petronas Towers]	8	Kuala Lumpur	88	452	1998
Petronas Tower 2 [Petronas Towers]	9	Kuala Lumpur	88	452	1998
Zifeng Tower	10	Nanjing	66	450	2010
Willis Tower	11	Chicago	108	442	1974
KK100	12	Shenzhen	100	442	2011
Guangzhou International Finance Center [Guangzhou Twin Towers]	13	Guangzhou	103	438	2010
Jin Mao Tower	14	Shanghai	88	421	1999
Two International Finance Centre [International Finance Centre]	15	Hong Kong	88	415	2003
Trump International Hotel & Tower	16	Chicago	92	415	2009
Princess Tower	17	Dubai	107	414	2012
Al Hamra Tower	18	Kuwait City	80	412	2011
23Marina	19	Dubai	89	395	2012
CITIC Plaza [CITIC Plaza]	20	Guangzhou	80	391	1997
Shun Hing Square [Shun Hing Square]	21	Shenzhen	69	384	1996
The Domain [Central Market]	22	Abu Dhabi	88	382	2013
Empire State Building	23	New York City	102	381	1931
Elite Residence	24	Dubai	91	380	2012
Central Plaza	25	Hong Kong	78	374	1992
Bank of China Tower	26	Hong Kong	70	367	1990
Bank of America Tower	27	New York City	58	366	2009
Almas Tower	28	Dubai	68	363	2009
The Pinnacle	29	Guangzhou	60	360	2012
JW Marriott Marquis Dubai 1 [JW Marriott Marquis Dubai]	30	Dubai	77	355	2012
JW Marriott Marquis Dubai 2 [JW Marriott Marquis Dubai]	31	Dubai	77	355	2014
Emirates Office Tower [Emirates Towers]	32	Dubai	54	355	2000

Table 3 (part 2). 2013 World Scyscrappers (SimArt, 2013)

Tuntex Sky Tower	33	Kaohsiung City	85	348	1997
Aon Center	34	Chicago	83	346	1973
The Center	35	Hong Kong	73	346	1998
The Torch	36	Dubai	84	345	2011
John Hancock Center	37	Chicago	100	344	1969

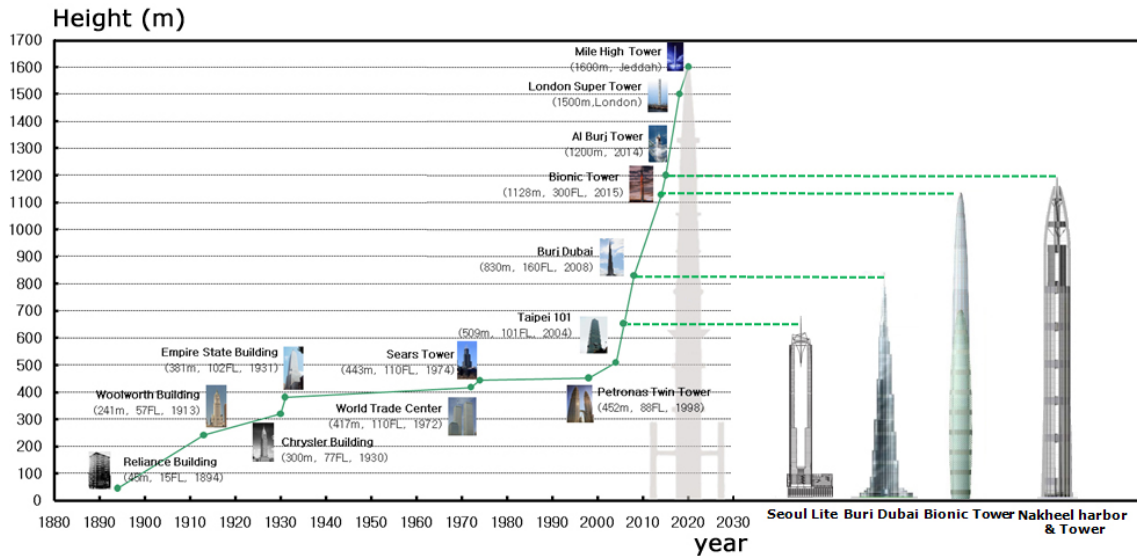


Figure 4. Global Trend and Plans of Super Tall Building (Ng, 2010).

The construction area of super tall building reflects the function and the trend of that time. Whereas the construction of super tall building centered on the United States in the past as seen in Table 4, in modern times, the construction of high-rises is prevalent in Asia and the Middle East. In addition, major materials for structure have changed from steel to concrete like in Fig.5 and multi-functional structure like in Table 5. The most significant change is that while in the past the impact of super tall building on cities as individual projects was not considered significant such as Empire State building or Sears Tower, the recent construction of high-rises such as Taipei 101 and Burj Dubai is underway as regional projects representing cities. This trend is advancing as high-rise construction reflecting sustainability which is a buzzword around the globe.

Table 4. Buildings over 150m shown according to location (Binder, 2008)

	1980	1995	2008 Plus Those Under construction	Those Under Construction Only
Americas	84.9 %	64.5 %	27.7 %	18.4 %
Asia/Oceania	9.9 %	31.2 %	59.0 %	54.5 %
Middle East	0.0 %	0.1 %	9.8 %	23.0 %
Africa	4.3 %	3.7 %	3.3 %	3.3 %
Total number of buildings	324	820	2922	877



Figure 5. Trend Change of Super Tall Building

Table 5. Buildings over 150m shown according to building use (IBEC, 2002)

	1980	1995	2008 Plus Those Under construction	Those Under Construction Only
Office	84.7%	78.3%	47.3%	26.8%
Mixed-use	5.2%	6.6%	11%	17.7%
Residential	5.2%	9.6%	35.3%	47.3%
Hotel	4.9%	5.5%	6.4%	8.2%

3 COMPACT CITY AND SUPER TALL BUILDINGS

3.1 Sustainable Compact City utilizing Super Tall Building

- Sustainability : concept balanced between environmental, economic, and social issues
- Example : Europe(ESSD), US(Growth management or smart growth)
- Sustainable super tall building doesn't release pollutants destroying the environment

Today's main theme in urban planning around the world is sustainability. Sustainability refers to a concept that comprehensively contains environmental, economical and social implication for intergenerational equity. In Europe, it is known as ESSD (Environmentally Sound and Sustainable Development, as growth management or smart growth in the United States.

Therefore, it is necessary more than ever to establish urban development strategies that recycle infinite land resources, improve efficiency and eco-friendliness of land use, reduce transportation and infrastructure cost, curb fossil fuel use and minimize damage on the environment and landscape. As one way to implement these strategies, a new standpoint is emerging as a means to pursue selective and focused development of high-rise-high-density away from polarized value assessment of either interest in development density or height, or, high-rise · high-density or low-rise · low-density. Sustainable super tall building doesn't release pollutants destroying the environment like the air, land and water. Furthermore, it lessens environment load making economic life possible and contribute to the community. The expansion-oriented industrialized large cities are adopting compact urban concept for sustainability and one of the most effective ways is to build sustainable super tall buildings through which already many nations are enhancing their urban and national competitiveness.

Another is the efficiency of sustainable super tall buildings in terms of the environment, society and the economy. Super tall building lessens environment load and establishes social and economic sustainability as well as efforts to build a new dimension of artistic and cultural sustainable high-rises through design multiplicity.

3.2 Benefits of sustainable super tall building

1) Efficiency of the economy and land use

- Re-use of land resources and protection of environment
- 24 hours usage of land through complex use
- A huge potential to create diverse and new economic added values

As for land use, super tall building boosts the merit of compact city as seen in Fig. 6 as it is developed with high-density in urban areas whose land prices are high.

Efficient land use doesn't not necessarily mean high-rise · high-density use of land in anywhere without any condition. According to the economic theory, in an area where there is more demand for land and accordingly high prices, high-rise · high density land use is required. On the other hand, in areas where there is more supply than demand for land and low price, it's better to use land based on low-rise and low density. Land prices are indicators showing relative scarcity of land resources in the market. So, high land prices mean that land should be used more economically because available land is limited. In areas whose prices are high, land should be used more intensively by increasing the input of relatively low-priced resources (buildings) compared to the land. On the contrary, low land prices imply that land can be used with more capacity so that in these areas, use should be used extensively by increasing the input of relatively low-priced land compared to other resources (buildings) (Choi, 2007).

Besides, places with high land prices do not limit their use of land only during the daytime or night hours focusing on the 'time' concept but make full use of land which is known as round-o'clock occupancy. For 24-hour land use, land should be used through MXD(Mixed Use Development), not for a single purpose. In this regard, super tall building is effective in dimensionally and vertically integrating various kinds of uses such as business, commerce, residence, accommodation, entertainment and culture. Plus, land resource can continue to be utilized at any time- day (business and commerce) and night (residence, accommodation, entertainment). After all, super tall building not only increases the 'intensity' of land use but also pursues multiple uses so that economic efficiency of land use can be improved. (see Figure 7)

In addition, dimensional and multiple use of land through super tall building has a huge potential to create diverse and new economic added values. The dimensional use of land increases urban brand value with landmark effect and finally it can attract more tourists as well as local residents. The multiple use of land prevents cities from becoming hollow because distance between workplace and residence is close, and also encourage diverse night activities revitalizing the local economy.



Figure 6. Efficiency of land use with super tall buildings in compact city (Mori, 2008)

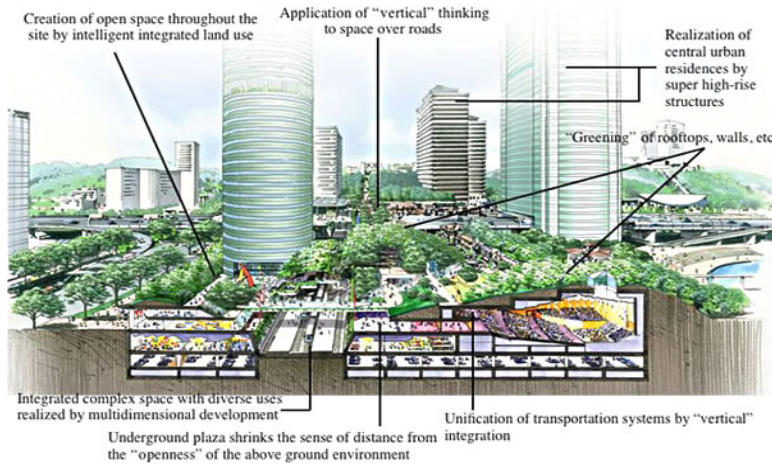


Figure 7. Vertical cities for multiple uses (Binder, 2008)

2) Benefits of transportation and social economic costs reduction.

- Energy saving and reduction of environment cost (air pollution)
- Creation of economic added value by three dimensional-complex usage
- Reduction of traffic expense
- Life Cycle Cost (LCC) less

Transportation and environmental costs reduce since cities can prevent extensive sprawl because there are super tall buildings in the center of the area from urban space structure perspective. When cities are expanded outside so that place for business and residence is separated, there will be heavy traffic on the road. In addition, the environmental costs will rise considerably because more vehicles accounting for 85% of the air pollution give off exhaust gas on the road. Therefore, dimensional and multiple use of land with super tall buildings in the center provide one-stop serve for various purposes such as business, commerce, entertainment and culture within the reach of public transportation, encouraging public transportation use and thereby reducing the use of cars. By encouraging public transportation, cities don't need to secure parking lots for cars and reduce transportation costs stemming from traffic congestion. Furthermore, cities can conserve energy and lessen the air pollution because they use less fossil fuel energy.

Lastly, there are energy conservation systems utilizing eco-friendly energy like BIPV System (Building Integrated Photovoltaic), Double Skin System and Wind Turbine System. Making full use of these systems can save energy several times more. Then the total life cycle cost (LCC) of super tall building become less than conventional low rise building.

3) Urban environmental benefits

- Reduction of infrastructure expense
- Supply of ground and vertical open space
- Secure city view's sense of freedom

It is necessary to secure more open space in order to improve urban environment in urban centers where there are many buildings. Super tall building has a positive effect on securing such open space and protecting the environment. Building high-rises by reducing the building-to-land ratio and applying the same floor area ratio can create more open space. Super tall building plays a positive role from the environmental perspective in that high-density development of brownfield and the reduction of new development field can prevent urban sprawl and protect green land or arable land (see Fig.5). In terms of open space, super tall building also supply vertical urban void as shown in Fig, 8, Seoul, Korea.

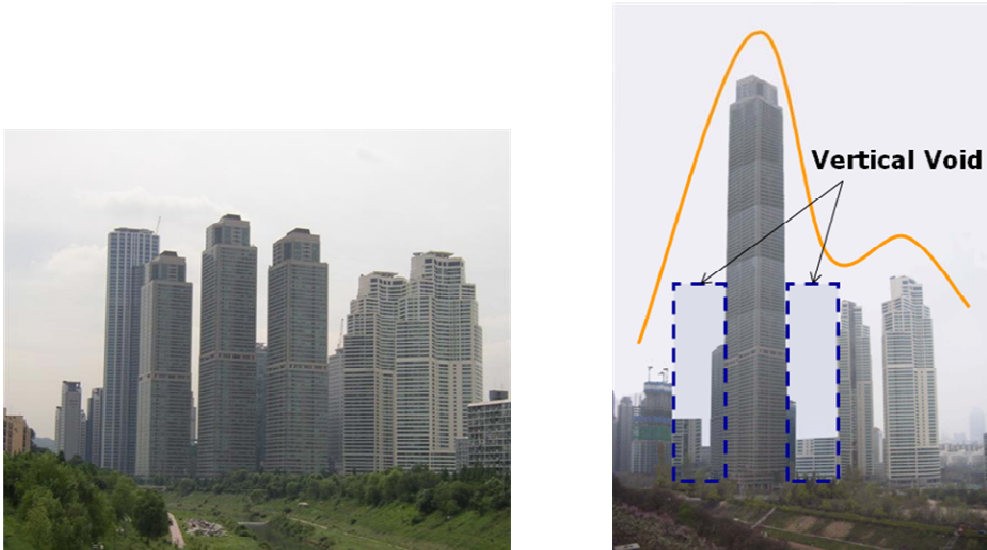


Figure 8. Super tall buildings vertical open space case, Seoul, Korea.

In this sense, super tall building becomes an effective means to improve the quality of public space by securing more idle space in the urban center.

On top of that, super tall building can reduce infrastructure costs because infrastructure including transportation such as subway and water supply and drainage system is already well in place. In other words, it is economically more cost effective to fix, expand and re-use the existing facilities than to create and provide a new infrastructure in the outer space of the cities. It easily brings about sustainable urban development.

Last, considering the eye level of pedestrians, additional increase of buildings' height has little marginal effect on pedestrians' closed views or feeling in the center where there are already many high-rises. Rather, given humans' purview, it is better to control the width of buildings not the height which is already beyond human scale. It is important to secure visual openness between buildings by constructing more tower-shaped buildings rather than box-shaped ones or to secure vertical public space by opening lower floors as shown in Fig. 9. Aside from that, sustainable super tall building can contribute to improving the quality of urban outer space by securing a certain open space between buildings, which is in particular true with mid-upper floors of buildings. Super tall building provides more vertical void for the entire city in the same floor space index than mid-rise buildings so that there is more view corridor and circulating urban air through more wind road (Yeo, 2012).



Figure 9. Singapore city Super Tall Building for vertical public space (Choi, 2007).

4 SUSTAINABLE SUPER TALL BUILDING TECHNOLOGY AND EXAMPLES

4.1 Sustainable super tall building technology

Super tall building itself is not environmentally-friendly and there has been much criticism over the sustainability. Aside from increasing construction costs, super tall building requires much energy consumption. This is because the upper floor of the buildings has different weather condition like a strong wind. As a result, in order to make the inside of the buildings similar to the ground floor, HVAC is required, which consumes lots of energy and increases maintenance cost. Due to the nature of closed outside structure, buildings depend on machines for ventilation, undermining living condition.

Hence, lately, there are innovative technological developments that tackle the problems like undermined living condition in super tall buildings and minimize energy consumption. Plus, the attention on sustainability in super tall building is high, away from simple competition in height.

This trend is fully reflected in the recently held special session (UIA, 2008) on Tall Building and Sustainability in the 23th UIA World Congress in Torino, Italy during June-July in 2006 and “Tall & Green: Typology for a sustainable urban future” (CHBUH, 2008a), the theme of CTBUH 2008 international conference. Super tall building shifts its focus from the competition in height to design variables utilizing BIM and low-energy technology, and also include the following technological elements.

The following is the relation between energy consumption and the increase in mass and height of building structures and suggests a variety of systems to address the problems.

4.1.1 Energy Consumption Characteristics with Building Scale

1) Area

Figure 10 shows America’s commercial buildings’ energy consumption in 2003 by the scale of the building. It is noted that even though floors are limited, the more building floor space increases, the more fuel consumption rises. And, as the height of the buildings rises, energy consumption per unit space increases as follows (EIAUS, 2006).

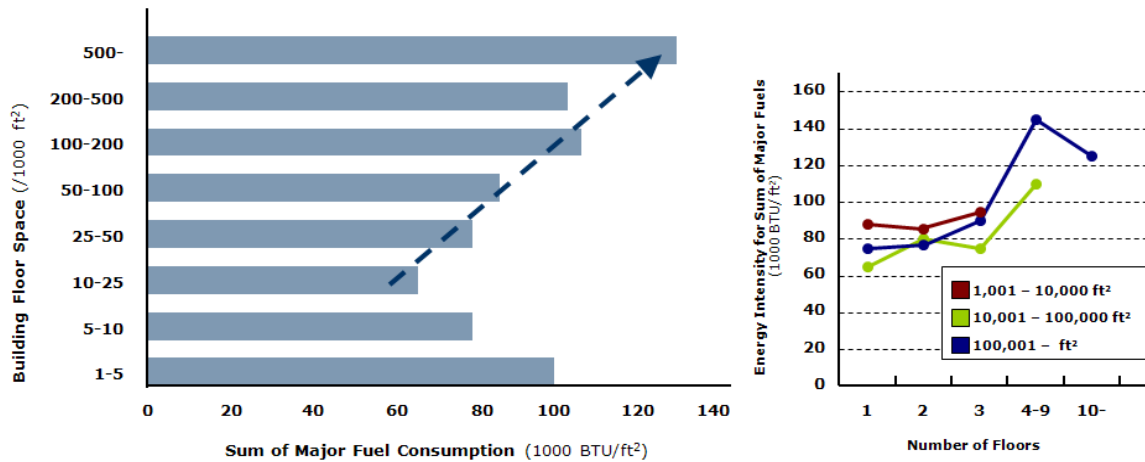


Figure 10. Consumption pattern based on buildings’ type

2) Mass

Figure 11 is a study result on the correlation between the scale of buildings and energy consumption. The study was carried out on buildings in China by Building Energy Research Center of TsinghuaHua University and shows that larger buildings require more energy (BERCTU, 2010).

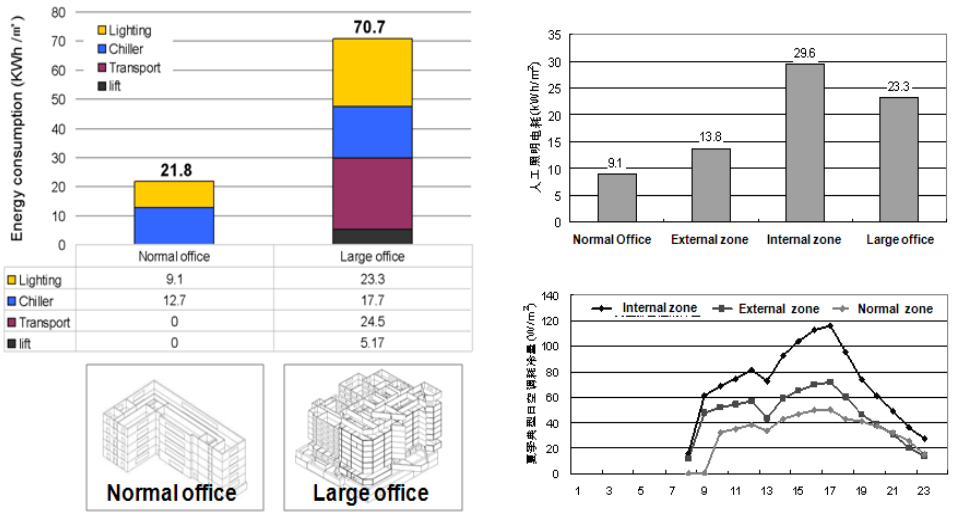


Figure 11. The ratio of energy consumption in large buildings.

4.1.2 Energy Saving Technology of Sustainable Tall Building

1) BIPV System (Building Integrated Photovoltaic)

There has been much development designed to take advantage of solar energy recently, among which technology development is ongoing for various designs in sustainable super tall buildings. In super tall buildings, BIPV system is used to utilize solar energy. High-rises are better to use the solar energy because they have more space to absorb the sun light compared to other buildings. Furthermore, as shown Fig.12, various designs can be applied by increasing the exterior size of the buildings for photovoltaic solar energy. BIPV panel can be applied with various kinds of colors and solar chip the sun reflects. As shown Fig.12, flexible BIPV system utilizing diverse designs is actively introduced (Pank et al. 2002).

- BIPV Systems contribute to the electronic energy supply of buildings themselves
- BIPV provides an opportunity for a clear path of direct sunlight
- Enough area to install PV panel
- Easy use to Super Tall Building
- Natural ventilation
- Improve energy efficiency and Good for health
- Economical efficiency
- Initial investment increases 8.5 % and Energy Consumption decreases 40 %
- Low LCC (Life Cycle Cost) required



Figure 12. BIPV System with Design Variation on Super Tall Building

2) Double Skin System

Double Skin System not only enhances energy efficiency with natural ventilation as its basic system but also is good for health. Also, it is very economical in terms of energy consumption – at first system increases the initial construction cost by 8.5%, but finally energy consumption drops by 40%, the system having low life cycle cost.(see Fig.13)



Figure 13. Double Skin System design Concept and Cases

3) Wind Turbine System

People have negative views on super tall buildings because they believe super tall building requires excessive energy. However, these days, wind turbine is installed on top of the building or in the middle of the building to adapt to and use natural wind as major alternative energy source.(Fig.14) Lately, like Seoul lite project(Seoul, Korea), system using the rising current of the air from the middle and lower part is being developed.

- Aerodynamic modeling is used to determine the optimum tower height, control systems, number of blades, and blade shape.



Figure 14. Wind Turbine System Cases

4) Rain Water Recycling System

As power and water consumption increases in super tall buildings, except water people drink or use to wash, purified through the sand and filter is stored in tanks and used. It can conserve wa-

ter energy and recently system purifying waste water is developed with waste water disposal facility. (See Fig.15)

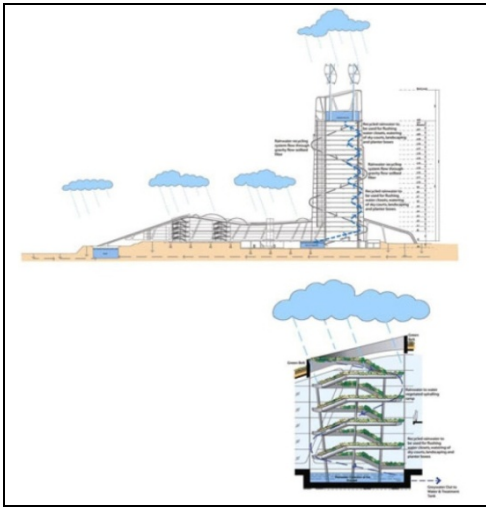


Figure 15. Rain Water Recycling and Collection Concept (CTBUH, 2008b)

5) Geothermal Energy System

Geothermal energy system uses geothermal power to get energy for heating and is mainly applied in areas with lots of geothermal energy or landfills. In the near future, geothermal energy will be more used because it is environmentally friendly energy source like solar power and wind. A case in point of geothermal energy use is Seoul lite and Shanghai tower. (see Fig.16)

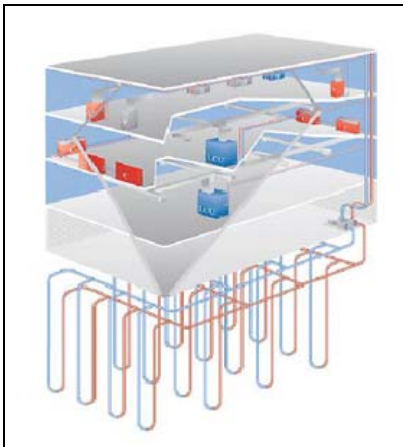


Fig. 16. Geothermal Energy System (Choi, 2012).

6) Passive daylighting System

Daylighting system is easily used co-friendly energy source. It was used in the past but due to the color change of indoor finish materials and glaring effect, the popularity declined. However, recently the system is re-emerging as eco-friendly policies are implemented to tackle the environment and energy problems.

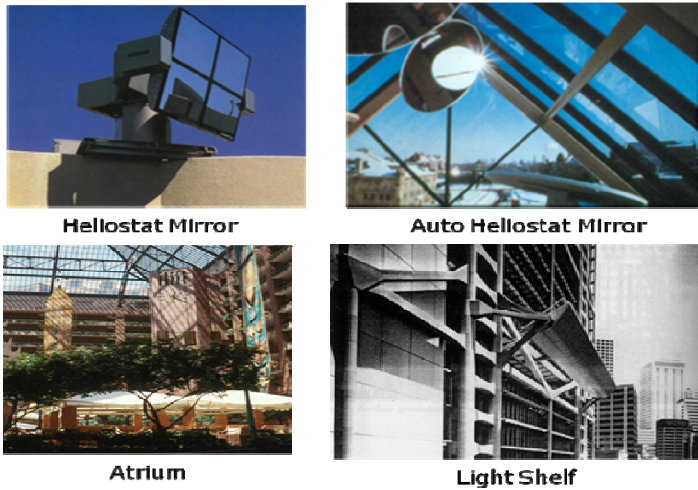


Figure 17. Passive daylighting System (CTBUH, 2008c)

4.2 Case Studies of sustainable super tall building¹⁾

As seen in Table 6, CTBUH rewards super tall buildings that achieve sustainability for high-rises and improved quality of urban environment. The reward is for construction that already has proved sustainability result and the assessment criteria are as follows.

Table 6. CTBUH sustainability assessment criteria

The environment	Adequate use of land, innovative use of construction materials, energy conservation, alternative energy use, minimizing the impact on the environment through reduction in water resource consumption and air pollution.
humans	positive impact on residents and their living quality
community	proved correlation between the present and future need of the community
economy	buildings boosting economic vitality for tenants, owners and community

1) Hearst Tower (USA)

New York's Hearst Tower was rewarded as the best sustainable super tall building of 2007 by the above 5 standards. (see Fig.18) The tower was constructed in 2006 and has 42-story (182m) housing corporate headquarter, commerce facility and other business. Awarded Gold Leed Certification by US Green Building Council, the tower provides panoramic view on Central Park and has effective diagrid design for heating, saving energy by 26% compared to other buildings. Thanks to this unique design, 2000 ton worth of steel is saved and 90% of used steel is recycled one. There is a tank storing 14,000 gallon of rainwater on the top of the building and that rain water is used in artificial waterfall and cooling system that grow water plants and manage the temperature and humidity of the lounge. This system reduces the amount of sewage by 25%. Aside from that, the tower uses variable air volume system, central air control system on the 18th floor, temperature control system on each floor, floor materials of radiant heating system for lounge heating, 100% external air cleaning cycle for auto-control, indoor air control system, sunlight sensing device, humidity sensing and controlling device, low-pollution materials, CO2 sensors and VOC.



Fig. 18. Hearst Tower(USA)

2) The EDITT Tower(Singapore)

A major idea of this 26-story building is vertical urbanization, which embodies the streets in vertical space. It has vertical landscaping and sky lounge with eco-friendly approach and tower design. There is a system accumulating and recycling rainwater on the top. As Expo tower, the high floors are for businesses and lower floors are for stores, exhibits and conference rooms, changing into offices or apartment later.

One of the issues of super tall buildings is a weak space connection. In order to address this issue, in huge pedestrian space for walks and shopping, there are cafes, performance stage and observation deck. By connection landscaping lamp with indigenous plants up to the 6th floor, public space is expanded vertically, highlighting space flow. This landscaping lamp is effective in conserving energy for cooling.(see Fig. 19)

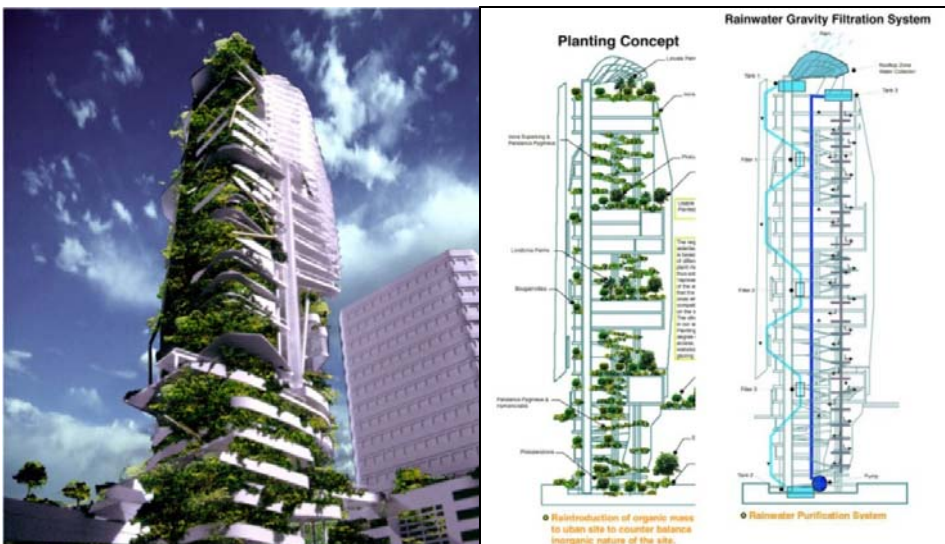


Fig. 19. The EDITT Tower(Singapore)

3) Chong Qing Tower(China)

Chong Qing Tower is designed for a company headquarter located in China's Chong Qing region(see Fig. 20). Spiral ramps stretching from the basement to the top of the building provide

natural ventilation function, lots of plants, sunlight and rainwater for the building. It has also a facility collecting rainwater and sunlight and photoelectric cell panels.



Fig. 20. Chong Qing Tower(China)

4) Eco Bay Complex(UAE)

Eco Bay Complex(see Fig.21) using the concept of eco-friendly green oasis serves as a series of parks and public network established in five buildings, connecting giant plaza on the ground to the top. Usually, complexes in this region have high access to the streets or are closed facilities that completely control the temperature and the climate. On the contrary, this complex combines two different types and is designed as shady pedestrian space of half-closed and natural cooling effects. Thanks to this traits, natural cooling, ventilation, humidification and shading for energy consumption is possible. The first purpose of this design is energy consumption through life cycle but visual symbol is also important.



Fig. 21 Eco Bay Complex(UAE)

5) Dynamic architecture(UAE)

Horizontal windmill of Dubai's dynamic architecture generates 0.3 megawatt of power and a total of 48 windmills are installed at the bottom of the building(see Fig.22). One windmill generates power that can be used for 50 households. As there are 200 households in this building, power generation from the other 44 windmills will go to neighboring buildings.

Italian architect, David Fisher, who designed this moving building, asks people to aggressively find out a new way rather than dwell on the present, saying "Right things are good, but good things are not always right."

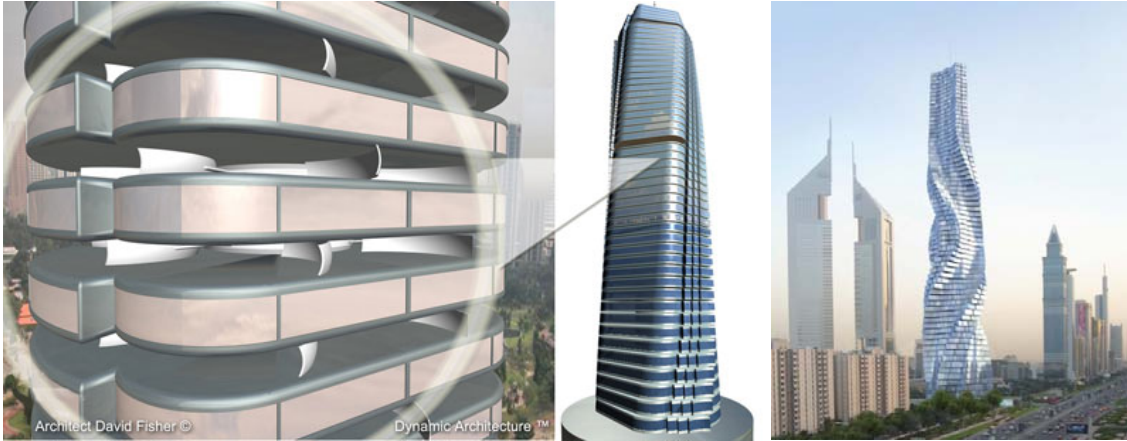


Fig. 22. Dynamic architecture (UAE)

6) Marina Bay Sands Hotel(Singapore)

Marina Bay Sands Hotel(Singapore) will be completely constructed in December 2009 with three stories below and fifty-seven above the ground. In particular, three buildings with a slope of 52 degrees converges on the 23th floor(70m). On the upper part of the building worth 200m height, three buildings are connected, creating Sky Park of 12,000 m² and increasing the hotel's connection.



Fig. 23. Marina Bay Sands Hotel(Singapore)

7) Seoul LITE (Seoul, Korea)

The building will be the world's tallest business tower complete with complex functions of a futuristic city, including office/residential spaces with pleasant environment, top-notch shopping malls, world-class cultural and exhibition facilities. The outward appearance of the building will be made in a style reminiscent of the windows of traditional Korean houses. Its design specifies the installation of an exterior super skin containing 40,000 LED panels that emits light of various colors as shown Fig. 24(a).

The 'interface void' (or bamboo-type) structure of the building will enable natural ventilation and wind power generation by utilizing the difference in air pressure between the ground level and the highest floor as shown Fig. 24(b).

A mirror installed in the building will direct sunlight towards the lower floors as shown Fig. 24(c). That, along with the use of geothermal heat and a photovoltaic generation system, using the side walls of the building, will make it possible to save considerable energy.

The greening of the rooftop of the lower sections of the building will bring about a heat insulation effect. The installation of automatic ventilation windows on the surface of the building will aid the supply of fresh air and save considerable energy.

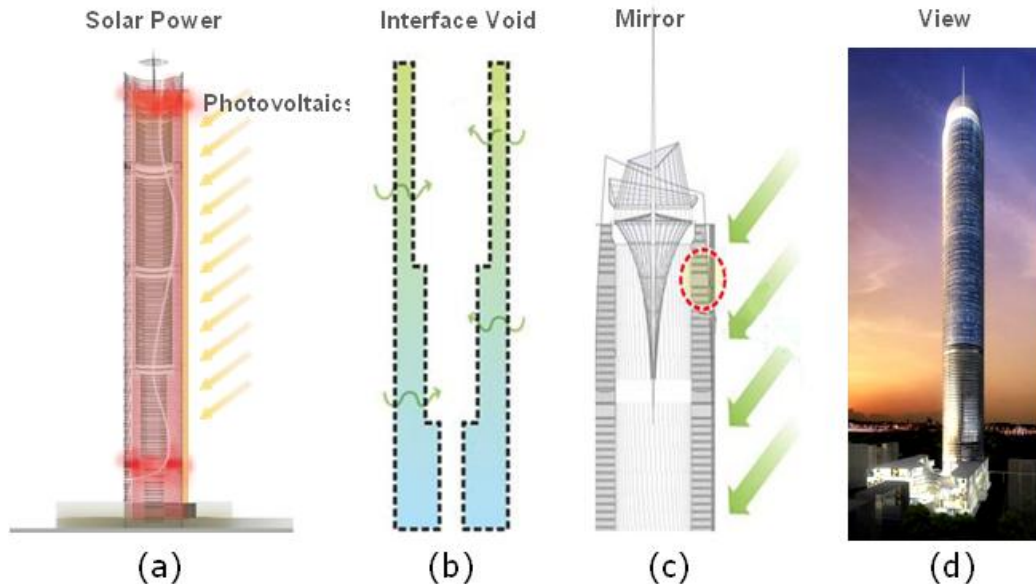


Fig. 24. Seoul LITE (Korea)

Buildings above connect the ground to the top vertically through horizontal distance of buildings with public square inside. This design integrates various environmental needs of society and cities, becoming visual symbol for sustainable life. This system, labeled a network of vertical gardens, satisfies two different needs at the same time: The first is for natural ventilation, cooling and humidification and finally air purification. The second need is for leisure and space for interaction.

5 CONCLUSIONS

As for construction, the economy and society have an inseparable connection. For instance, the World War 2 created concrete box-type buildings for the purpose of post-war recovery. The first oil shock made glass atrium for natural light in fashion around the world. Now, super tall buildings that are meaningful as strategic goods for improving urban competitiveness has emerged as a new driving force for construction industry and at the same time have faced the challenge of economic and environmental sustainability. Accordingly, a way to maintain ESSD, preserving the environment is highlighted.

This paper looks through needs and examples of sustainable super tall buildings in compact city. On the conclusion, in recent super tall buildings, rather than the height and total stories, space openness, functions and design become more important. In addition, environmental-friendliness is vital more than ever and super tall buildings play a important role in creating energy-conservative urban structure in compact city.

Modernism construction of Mies van der Rohe, famous for the phrase “Form follow function” has changed into the phrase “Form follow environmental” in modern super tall buildings. In other words, as super tall buildings evolve into embracing activities and functions unexpected in the past, the use and height will increase further.

Hence, super tall building will develop further to maximize its advantage such as realizing compact city and serving as an artificial tourism attraction by overcoming high construction and maintenance costs.

REMARKS

- Tall building is not good or evil, it is a choice
- Tall buildings succeed to the urban history, culture and spirit.
- Tall buildings bring a matter to a social, economical, environmental settlement sus-

tainably.

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