CASE-IN-POINT 2020

SUSTAINABLE DESIGN FOR TALL BUILDINGS

Adapting cities through renewable energy sourcing

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ABSTRACT

In several cities, mid and high-rise towers dominate the skyline, as vacant land is growing scarce in urban centers the only way to build is up. Tall buildings play a strategic role in the social, economic and environmental sustainability of a city. These towers can also offer a critical mass to achieving complete communities with this mixing of land uses. However, the taller the building the more energy it will consume and the more greenhouse gases they produce.

1.0 INTRODUCTION

As cities continue to grow, the way buildings are constructed and managed has never been more critical to their impact on the environment. Sustainable design can offset a building's environmental impact by its overall performance of materials used, the exterior design, and the quality of the internal environment. The guiding principles of sustainable design are to maximize energy efficiency and promote sustainable design to reduce resource and energy consumption, and carbon footprint on the built environment. Sustainable design strategies are "...a set of actions aimed at improving the environmental, health, and socio-economic performance of all types of buildings in the city" (City of Edmonton, 2012).

FIGURE 1 | Guangzhou City at Night

2.0 BACKGROUND

Increasing urbanisation in recent decades has created a surge in the construction of towers and tall buildings worldwide. There is a growing demand for cities, provinces and countries to become more sustainable and energy efficient. It is estimated 70% of the population will be living

FIGURE 2 | Guangzhou Sustainable Master Plan Rendering

in cities by 2050, a significant increase from the approximate 55% today. Cities account for 70% of the greenhouse-gas emissions, 30% of which is generated by buildings (National Geographic, 2017).

Many countries worldwide have made commitments to minimizing their impact on the environment. Cities, however, are dealing with the increase in population and need to fulfill these sustainable policies. Urban planners, architects, engineers and city officials try to do what is best for the city at the present time but also need to keep in mind the impacts it will cause on the environment and future generations.

The practice of sustainable building refers to several approaches in the process of implementing building projects that involve less harm to the environment. A sustainable building should achieve several objectives: resource and energy efficiency; carbon dioxide (CO2) and greenhouse gas emissions reduction; pollution prevention; mitigation of noise; improved indoor air quality; harmonization with the environment (Akadiri, Chinyio & Olomolaiye, 2012).

Tall buildings can change the surrounding microclimate with wind funneling at the base making conditions unpleasant for pedestrians. They cast shadows and block sunlight. They can also be environmentally damaging if they have inefficient heating, cooling, and ventilation operating systems that consume large amounts of energy. Tall buildings

do have the potential to be more environmentally friendly through design by taking advantage of the surrounding conditions through the incorporation of systems such as solar panels and wind turbines (Ali & Al-Kodmany, 2017). A sustainable project is designed, built, renovated, operated or reused in a holistic, ecological and resource efficient manner (Akadiri, Chinyio & Olomolaiye, 2012).

So how does a densely population urban centre address the challenges of being sustainable? Cities around the world are incorporating sustainable design strategies to answer the call to minimize their negative impact. Taller buildings have been a focus as because they can lessen city sprawl and accommodate a large amount of people and offer many functions in one structure. These towers, however, consume large amounts of energy and resources starting from construction, to its continued operation and then to its demolition. The vision of sustainable design of taller buildings is one of an environmentally conscious, energy saving structure that utilizes responsive and renewable materials and systems. The buildings goal is essentially to be an ecological balance (Ali & Armstrong, 2008).

> **"…an integrated and holistic approach to assessing performance and value in order to meet multiple goals and maximize the efficiency of multiple systems."**
>
> **— City of Seattle, 2011**

Newer technology has allowed for buildings to be more sustainable as there are many examples of sustainable buildings worldwide. This Case-in-point explores how design of The Pearl River Tower, located in Guangzhou, China, aims to resolve some of the impact tall buildings have on the environment. The design combines active and passive sustainable measures to reduce its impact and dependency on the local electrical grid, reduce carbon emissions, and provide an optimal interior environment for its occupants.

FIGURE 3 | Pearl River Tower

3.0 / THE CASE

Guangzhou, China, like many growing cities, is dealing with a large population and the coinciding requirement to provide energy to the homes and buildings. Providing electricity to millions of people and trying to respond to climate change has become a difficult balance when relying on non-renewable resources for power.

The Pearl River Tower, located in Guangzhou, Guangdong province, China is one of the first carbon-neutral towers at the time of construction completion in 2011. During the design phase of the building, the Government of China released its National Climate Change Program, in 2007. The plan outlined strategies to address climate change that included the mitigation of greenhouse

FIGURE 4 | Pearl River Tower Wind Turbine

gas emissions and adapting to the consequences of climate change. Within the Program, there are goals to reduce emissions, lower energy intensity 10% by 2010 and to double renewable energy use by 2020.

The Pearl River Tower stands over 309-meters (1,000ft) and was designed to be one of the world's most sustainable highest-performing tall buildings (CTBUH, 2014). Some of the feature to this 71-storey building includes:

- Exterior façade
- Wind Turbines
- Integrated solar panels/photovoltaics (PVs)
- Radiant cooling and underfloor air ventilation
- Daylight-responsive controls
- Daylight reflectors
- High-efficiency lighting
- Vertical transportation
- High-efficiency chiller system
- Greywater collection system

Designed in partnership with Chicago-based Skidmore, Owings & Merrill (SOM) and Guangzhou Design Institute, the original goal was to construct the first net-zero tall building in the world and to sell the surplus power to the local power company. Unfortunately, at the time, this goal was not achievable. The building consumes 60% less energy than a traditional building of similar size. It is the first supertall buildings to receive the highest level of sustainable design, LEED Platinum, by the US Green Building Council CTBUH, 2014).

Energy generation

Pearl River Tower's reduced energy demand is achieved through four openings at the mechanical floors that house wind turbines. The wind is channeled to the openings by the strategic contour design of the façade. The wind is drawn through the building's body to the turbines, which generates electricity for the offices within. In addition, the wind is also pulled into the building and routed through the ventilation system. The turbines can generate approximately 1m kilowatt hours of electricity a year.

Building orientation

The building was positioned to take advantage of the sun and wind patterns of the location. The shape, angle and the south facing direction of the tower is intended to optimise exposure to the sun's path, to produce electricity via solar panels within its east and west facades. The panels, along side the turbines, energize the heating, cooling and ventilation of the building. The use of natural lighting was a priority and is maximized by controls that respond to the light and manipulate the automated blinds. The blinds are also equipped with solar panel cells, so the building continues to harvest the sun's energy even when closed.

> **"The incorporation of wind turbines into tall buildings is becoming increasingly common as a method of both reducing carbon footprint and making a very public statement about a building's green credentials."**
>
> **— Denoon & al., 2008**

Climate control

The internal cooling system works to keep the temperature at a desirable level during the summer heat for the building's tenant's while saving energy. This is achieved by radiant ceiling technology that uses piped water to keep the internal space cool, eliminating the need for costly and energy-heavy air conditioning units. The building's façade has a

double layer that traps the heat from the sun and is repurposed as energy to power the building. The Pearl River Tower is also equipped with motorized louvers on the facade of the building that rotate to keep the building cool and provide fresh air ventilation.

The deputy director of the Urban Planning and Research Centre stated in 2009 that Guangzhou had expanded too quickly and that there is a need for the city to focus on becoming more energy efficient (Watts, 2009). Many energy efficient buildings rely on add-on technology to generate sustainable energy; such as roof covered in solar panels. The Pearl River Tower has exceeded this by becoming a structure that was built to generate energy.

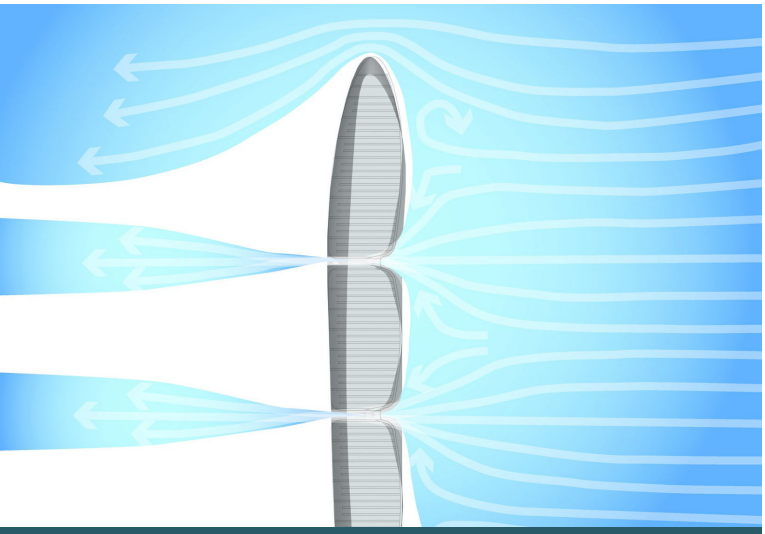

FIGURE 5 | Pearl River Tower Wind Rendering

4.0 LESSONS LEARNED

Cost effectiveness of sustainable building design

A large factor in any development is the cost and return on the investment. It is estimated that the Pearl River Tower costs to incorporate the sustainable features added $13 million to the construction costs. The projected return of the extra costs was about five years. This encompassed the saving on energy bills, rents and lower maintenance costs. These up-front costs can be a deterrent to sustainable design.

Environmental costs

A more sustainable practice to building development and utilizing renewable energy sources is beneficial to the environment. Utilizing renewable energy sources to solely power, or to assist in powering, a building helps with resource diversification for energy. For some cities the cost of electricity may be cheaper, creating a deterrent for those to invest into expensive materials even if it is more beneficial for the environment as the cost savings in energy are no greater than standard energy practices. There is also the risk is that the materials used to create the sustainable equipment is only shifting the negative environmental impact burden to other places.

Technology

New technologies are constantly being developed and updated to match current practices in creating sustainable structures. The common objective is that buildings are designed to reduce the overall impact on the built and natural environment, as well as aiming to improve overall human health.

With technology developing at a rapid pace, much of the equipment and parts for these systems are not massed produced so materials and equipment costs are high. New technology also means that there may be a shortage of knowledgeable technicians that are able to maintain or repair equipment.

The new technology needs to provide evidence that it will deliver on the claim of being more sustainable and whether or not the equipment can generate enough power to run a building.

Safety concerns

A concern of liability and safety would need to be addressed when a tall building incorporates a large wind turbine either enclosed or not enclosed. Failures and aging to mechanical equipment could have disastrous effect to any persons or objects within or surrounding the building. As urban centers are more populated, wind turbines can pose a greater risk to people in those areas than that of a turbine in a rural setting with where the population is lower.

Precedent developments

As more buildings are constructed with the goal of being net-zero, or close to net-zero, the more lessons are learned for practitioners. Planners and city officials can make better decisions on polices and regulations if there are numerous precedencies to build a case for more sustainable technology the is on the fringe than being mainstream. The cost of equipment and materials should also start to become cheaper as the demand for parts increase.

Renewable energy technology and planning

The technology for sustainable building moves much faster than the policy process. For urban planning there are many implications: site selection, (re)zoning, stakeholder engagement, and mediating social, economical and ecological constraints. Many cities may not have policies set in place and comprehensive plans may only get reviewed every 5-10 years, depending on the type of plan and the capacity of the local jurisdiction. This puts urban planners at a disadvantage for more sustainable development.

Long- and short-term sustainable goals

Long- and short-term rewards, may be the cost effectiveness of using passive energy design to save on monthly energy bills (short term) and potentially save on on-going maintenance costs (long term) depending on the life space of the infrastructure.

Site selection and orientation

The site of the building is key to the renewable energy harvesting. Depending on the climate, there could be a lot of wind generated in a downtown area because of the way buildings are situated. This could be beneficial. There would need to be some studies on how future developments may impact the functionality of possible blocking of winds. Cities with more sun may benefit more from using more solar technology than wind power and vise-versa.

5.0 / CONCLUSION

In response to climate change, many country's decision-makers have adopted strategies that promote the use of renewable energies. As the world's urban population continues to expand and cities continue producing a vast amount of emissions that puts a strain on the environment, engineers, architects, and planners are challenged to find ways to make cities more sustainable. The case study offers a look at what is possible within a city, but it also challenges the status quo of land use and zoning by-laws. For planners, it becomes a push for changes to land use planning as it helps influence urban areas and neighborhoods into healthier, more efficient spaces. As new technology continues to shape the way we live, sustainable design for tall buildings could hold a solution to high-density urban areas becoming more energy efficient while generating less pollution.

FIGURE 6 | Guangzhou City Towers

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Image Resources

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