A Column of Time:
An ecological tower for Taichung, Taiwan

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ABSTRACT: This paper presents ecological design ideas for one of the five finalist proposals in the international competition for the Taichung Tower in Taiwan. Even though high rise buildings are typically energy intensive, this tower is proposed as a living organism that regenerates the environment, heals the planet, the city, and its people, encouraging sustainable living for the citizens of Taichung. Several strategies are implemented to achieve this and are organized using a carbon neutral process that organizes them in the areas of construction, water, waste and transportation as integrated systems in different scales: regional, site and building. We proposed to reduce building loads through an envelope design that maximized passive cooling strategies and daylighting while reducing direct solar gain. Some of the proposed strategies are well proven and help to shape the building skin, however because this proposal was for an international competition other more speculative strategies are also implemented. Simulations, diagrams and images of the project are presented together with explanations of the systems and how they affected the form of the tower.
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INTRODUCTION
Even though high rise buildings are usually energy intensive, this tower is proposed as a net positive building that regenerates the environment, heals the planet, the city, and its people encouraging sustainable living for the citizens of Taichung. Several traditional and non-traditional energy, construction, water, waste, and transportation strategies were incorporated in the design of the building to reduce its environmental footprint resulting in a tower that produces more energy than it uses, captures and treats most of its water, and generates minimum waste. Building integrated photovoltaic panels follow the position of the sun, shading the interior and reducing solar gain. When the sun is low in the sky, the panels are more horizontal, allowing more daylight into the interior. The building responds to wind patterns at different heights, resulting in an asymmetrical and helicoidal form. Wind is accelerated and harvested into turbines located inside aerodynamically sculpted openings and converted into clean energy. The tower reuses most of its water through a combination of systems: rainwater is used in toilets and is then sent, with water from fixtures that use potable water, to living technology systems located in several points in the tower. Indoor and outdoor water conservation measures are implemented to further reduce water consumption. Nitrogen from the Living Technology Systems is used as nutrient for the algae farms which use this and other nutrients activated by solar energy to produce bio fuels that are used for transportation. Displacement air is introduced at floor level at 16°C and air exhaust is at the ceiling in most of the spaces.

GENERAL DESIGN CONCEPT
Rising from its roots that are infused with its people, place, history, and stories, this column of life is the culmination of the unique serendipitous life-style and inclusive multicultural dynamism of Taiwan. The Tower sustains a creative synergy between structure and its context through a physical, visual, and metaphysical morphology. The very roots that shaped this tower are ingrained in the memories of its past histories and stories of its land, of Taiwan, while it continues to foster a celebration of life, and its ever-changing aspect of history making.

As opposed to the past precedents of towers being a distant object commemorating the past, the proposed tower enforces interconnectivity to its context in multiple dimensions. It is in constant engagement with its people and place as a farm of renewable energy giving back to its community, an education center promoting sustainable living, an urban synthesizer fostering chance encountering between people, and an ever evolving time capsule capturing the stories of the place. It becomes an icon for the city of Taichung by relating to its spirit of place and allowing new meanings of history to be experienced and acquired over time.
The tower is in essence an ever evolving and unfolding capsule of time and a story book that captures and reflects the life of the strength and resilience of the people of Taiwan in embracing the evolution of Taiwan’s cultural diversity.

A beacon 400 meters in the sky overcomes topographic barriers, calling to the Taiwan Strait to the West and the neighboring downtown district of Taichung City to the Southeast, while influencing urban vitality throughout Gateway Park (Fig. 1).

The tower’s architecture is a choreography of spatial movements, stories of the place, structure and sustainable design. Shaped by the visual and physical history and memory since the founding of the City of Taichung, the design takes a fundamentally enigmatic form and continues to nurture the interactive evolution between space, time, experience, and its architecture (Fig. 2).

The tower is conceived as an adaptable organism onto which new envelope technologies can be experimented. A modular transparent skin brings interchangeability and adaptability to new technologies and climatic responses. The tower evolves into a vertical container of exhibitions, where cultural events, social gatherings, demonstrative learning, energy production, as well as festivities and celebrations take place.

The tower is designed to sequester carbon, removing it from the atmosphere by generating more energy than it uses. In addition to being part of the Research and Development Innovation Zone the tower will be a beacon for promoting sustainable living through itself as an experimental farm for sustainable technologies showcasing Taiwan’s initiative toward low-carbon urban development and ever evolving technological advances. The model green tower of today will not freeze in time as it is a modulated structure with skin systems evolving to adapt to the latest building technology, creating a seasonal and breathing aesthetics.

Located in Gateway Park, the tower acts as a linkage between multiple neighborhoods and merges visually and physically with the green space and urban districts around it to create a fully integrated precinct. Rising from the landscape, the tower is visible to all of Taichung - acting as an urban symbol for the region and a marker for the new Gateway City (Fig. 3).

SUSTAINABLE STRATEGIES AND CARBON FOOTPRINT

As already discussed, we have envisioned this tower as a living organism that regenerates the environment, heals the planet, the city, and its people encouraging sustainable living for the citizens of Taichung. Effective energy, construction, water, waste, and transportation strategies reduce the building’s environmental footprint so that it becomes a living building that produces more energy than it uses, captures and treats most of its water, and generates minimum waste.

Because of the hot climate, several simple well known strategies [1] are first implemented to reduce overheating. These strategies are mostly connected with the building
envelope to optimize its energy performance balancing daylight, thermal and acoustical performances. Green roof gardens maintain ecosystem connections and create natural habitat, while the limited amount of roofs are light colored to reduce the heat island effect. Potable water usage is reduced through rain and moisture collection and low flow plumbing fixtures. Photovoltaics offset the consumption of non-renewable energy and carbon dioxide emissions. The use of local and highly recycled content materials is maximized.

**Carbon Footprint**
Reducing the carbon footprint of the tower was one of the most important overall design goals. It is clear that significant reductions in emissions will only be possible if significant reductions in energy consumption in buildings are implemented. However, energy use is not the only source of Green House Gas (GHG) emissions from buildings, and buildings are also responsible for the emission of GHG through their operation, construction, water use, and the production of waste. Indirectly they also affect transportation emissions from the vehicles that come and go to the building site.

Emissions are produced as a direct result of interactions between the building and the external environment that surrounds it. These interactions can be affected by the building fabric and materials or the building’s inputs and outputs (operation, construction, water, waste) [Eq. 1].

\[ T_{be} = O_{e} + C_{e} + W_{e} + W_{a} \]  Eq. 1

Where the emissions are from:

- \( T_{be} = \) Total Building
- \( O_{e} = \) Operation (energy)
- \( C_{e} = \) Construction
- \( W_{e} = \) Water
- \( W_{a} = \) Waste

and if we consider transportation then:

\[ T_{be} = O_{e} + C_{e} + W_{e} + W_{a} + T_{e} \]  Eq. 2

\( T_{e} = \) Transportation

To better organize these ideas, a carbon neutral design process developed by one of the authors was implemented in which the strategies are included in a diagram that organizes the strategies during the design process [2,3,4]. This diagram can be continually refined and updated as needed, per specific requirements, becoming a roadmap during the design process. In this diagram (Fig 4), the five horizontal bands are the sources of emissions (both direct and indirect) previously discussed: operation, construction, water, waste and transportation. The first column describes their baseline requirements and the final column, not included in this diagram, describes what was actually achieved for each one, the outcomes. The columns between these two contain the strategies to achieve the goals organized according to the to the scales in the process, from the regional-urban scale to the site, the building envelope and finally the interior of the building. Different strategies are located at the intersection of the columns and the bands, and are represented with colored rectangles. Some of these strategies are discussed in the following section.

**Figure 4: Carbon Footprint Reduction Strategies**

**Renewable Energy**
The three renewable energy producing strategies that are implemented in the building are solar photovoltaic, wind energy, and kinetic energy. We calculated that 145% of the required energy would be produced by the PV system, 30% by the wind turbines and up to 10% by kinetic energy. Overall the tower is producing 185% of the energy that it will use. It is important to explain that this is achievable because many energy efficiency strategies have been implemented and the tower does not contain a very large program.

**Figure 5: Solar Radiation analysis of the Skin**
The first step to implement the systems is to sculpt the form to select the best location for the PV panels analyzing incident solar radiation on the exterior surface (Fig. 5). This permitted to select optimum location for the components of the louver systems for shading, energy, green etc. (Fig. 6). Building integrated photovoltaic panels would be mostly placed on the south eastern façade, towards the zenith following the position of the sun and in the outdoor area around the building. The building responds to potentially different wind patterns at different heights resulting in an asymmetrical and helicoidal form. Wind is accelerated and harvested into turbines located inside aerodynamically sculpted openings and converted into clean energy (Fig. 6).

Adaptable Building Skin

The building skin design is integral to the sustainability strategies. A shading system consisting of modular components prevents excessive solar heat gains and glare and adjusts to allow adaptation to varying solar conditions and allow unobstructed views where desired. These modular components have further performative characteristics depending upon their location and orientation on the building surface, including louveres containing photovoltaics for building electricity needs and solar hot water as needed to meet program demands. Additional system components provide vegetated surfaces supporting the growth of native and endemic plant species, creating a refuge and resting point for local insects and birds and increasing the biodiversity of the surrounding park and city. We propose this system to be truly modular and reconfigurable, allowing the integration of experimental technologies and other newly developing sustainable systems as they are developed (Fig 7). As such the building skin becomes a place to not only meet immediate building needs, but to foster innovation and testing of future sustainable technologies in a real world laboratory.

Daylight

After finding the most radiation intensive locations some of these modular louvers have been designed to follow the sun (Fig 8). Panels receive sunlight when sun is high, shading the interior and reducing solar gain. When sun is low, the panels are more horizontal, allowing more daylight into the interior [5,6,7].

Figure 7: Modular exterior elements.

Figure 8: Operable Exterior Elements

Figure 9: Illuminance levels provided by daylight.
Daylight levels inside several spaces were studied at different times and window dimensions and shading systems were adjusted to provide sufficient daylight with minimum glare and heat gain (Fig 9).

**Thermal Comfort**
The occupied spaces are controlled to provide occupant comfort in accordance with ISO 7730 (Fig. 10). Using different analysis methods and software the occupant comfort levels are maintained at 10% Percentage Person Dissatisfied (PPD) or less during occupied periods throughout the year [8,9,10,11].

![Figure 10: Thermal comfort levels for a typical floor](image)

**Water**
The tower reuses most of its water through a combination of systems. Rainwater is used in toilets and is then sent, with water from fixtures that use potable water, to living technology systems located in several points in the tower (Fig 11). The class A water that comes out of these systems is used for irrigation in the different roof gardens and excess water is sent to the aquifer. Indoor and outdoor water conservation measures are implemented to further reduce water consumption. Due to the high humidity content in Taichung, water will be condensed from the air by lowering the surface temperature of the North side of the large tubular structures below dew point.

Nitrogen from the Living Technology Systems is used as nutrient for the algae farms which use it and other nutrients activated by solar energy to produce bio fuels that are used for transportation while sequestering additional carbon dioxide from the atmosphere in this process (Fig 11). This carbon dioxide is still released to the atmosphere when the biofuel is combusted, however it is not new carbon that is being added from locked resources.

**Mechanical Systems**
The occupied spaces are conditioned by a hybrid displacement ventilation system together with a radiant floor for heating and cooling. Displacement air is introduced at floor level at 16°C and air exhaust is at the ceiling, providing 30-35% better ventilation effectiveness and substantial savings in first cost and operating cost. The radiant floor is operated between 19 °C in cooling mode to a maximum of 18 °C in heating mode. The radiant component regulates the mean radiant exchange in the space which improves occupant comfort [12,13,14,15,16].
**Green Building Certification**

An energy calculation of CO2 reduction per day and year show an optimally performing building in accordance to Taiwan’s sustainable urban and rural development policies.

**CONCLUSION**

The tower harnesses wind, solar energy and rainwater and releases only recycled water, surplus energy and a small amount of waste to the environment. Its design takes a radically different approach to energy self-sufficiency: not only does the tower supply all of its annual energy needs via renewable sources on site. The building produces an additional 85% of its typical energy needs, clean energy that is sent back into the municipal grid of Taichung for use by the surrounding city. This energy replaces non-renewables which are currently supplying this area, and by virtue of being a local source eliminates the significant transmission losses that currently exist. The result: the tower has a net negative carbon footprint.

We estimate that with all sources of on site energy the tower is producing 8,440,000 kWh/yr and the building is using 4,577,126 kWh/yr this is equivalent to a surplus of 9,662,593 kg CO2e/yr equivalent to about 250,000 trees.

**REFERENCES**


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