**The Green Tornado Complex**

Upon hearing the word tornado, a gloomy scene of destruction and devastation conjures up in one’s mind. In effect, tornado is a natural phenomenon which swallows objects on its whirling path into annihilation. Consequently, it is said to be an icon of damage and destruction. This matter is expressly palpable and perceptible in the pacific coasts. Now imagine that we have a sort of tornado which swallows energy and sucks in different forms of energy present in nature in a way that we can exploit this absorbed energy to supply for our needs. Given this possibility, would anyone consider such a whirlwind threatening and destructive like other hurricanes?! Of course not! The main idea behind our proposal in this project, which is called Green Tornado Complex (GTC), is designing such a tornado in an architectural manner which swallows energy and, by its optimized performance in green energy absorption, it both serves human society and ecology and symbolizes a generation of clean energy from infinite and sometimes unharnessed sources in nature.

The present proposal of the GTC, follows three cardinal objectives: (1) Using different sources of green energy, including solar energy, wind and wave energy to produce green electricity; (2) Turning the GTC project into an iconic building having a conceptual relation with its surrounding site and creating a new and forceful identity for Santa Monica Pier; (3) Creating a public space for visitors and people in general. Structurally, the proposed project consists of two chief sections: (i) Tornado Tower; (ii) Green Passage.

The Tornado Tower, which has been designed as an icon of possibility indicating that once destructive phenomena of nature can be tamed to be useful and functional, is in tornado shape and has a stable structure. This tower imbibes two different forms of energy, namely; solar energy and wind energy, and using a mechanism that will be explicated in the following, turns them into electrical energy. Regarding its architectural design, this tower comprises of several asymmetrical funnel-shaped building elements fitted concentrically along a cylindrical core in the center and placed at uneven distances from one another. Dimensions and sizes used in the design are presented in the split pieces depicted in the presented figures. The tower consists of two main sections: the *roof* and the *shell*.

The *roof* has been designed so as to absorb solar energy and turn it to electricity. This section, which is round and concave in design, uses a solar power tower which consists of an array of dual-axis tracking reflectors and a central receiver atop the tower. The receiver contains a fluid deposit, which can consist of [sea water](https://en.wikipedia.org/wiki/Sea_water). Computer-controlled flat mirrors (called heliostats) track the sun along two axes and focus solar energy on the receiver at the top of the Tornado Tower. The focused energy is used to heat seawater (over 1,000° F) which is then transferred to a heat exchanger to produce steam and run a central power generator. By using molten salt, which has a high heat capacity, as a transfer fluid and thermal energy storage medium, energy storage can be efficiently incorporated with this project, allowing for 24 hour power generation.

The *shell*, on the other hand, absorbs and transforms wind energy. This part of the tower is simply a multi-storey wind capturing and delivery system that funnels wind energy to some conversion systems to convert the accelerated wind to electrical power. In fact, the tower body is designed so that it captures, accelerates, and concentrates wind stream, and converts it into electrical power when wind is at its optimum state of energy. The five key components of this tower are (1) intakes, (2) accelerating channels, (3) Venturi sections, (4) turbine/generators, and (5) exit openings. The omnidirectional intake areas allow wind collection from any direction. When air stream passes through the intakes and proceeds towards the accelerating channels, it continuously speeds up. Wind is then concentrated and further accelerated in the Venturi Effect sections of the tower. In other words, instead of snatching bits of energy from the wind as it passes through the blades of a rotor, the Tornado Tower captures wind with several funnels and directs it through some tapering passageways that passively and naturally accelerate its flow. This stream of wind energy is then delivered to some small turbine/generators installed safely and economically at ground or upper-ground levels to convert the accelerated wind to electrical power. Finally, air returns to nature through the exit openings.

The Green Passage, which is designed as a roofed public space, symbolizes a passageway that guides the public towards a green world of clean power production with fantastic vistas and beautiful horizons. In this section, wave energy is used to generate electricity. Structurally, this part of site, with an approximate length of 350m and approximate entrance radius of 15m is designed in such a fashion that allows optimum exploitation of wave energy. It is noteworthy that the design of Green Passage along coastline and the arrangement of several breakwaters underneath this space have made the utilization of wave energy possible in view of the fact that the project site lies parallel to the pier and wave movement is perpendicular to the extension of this site. In this project, Oscillating Water Columns (OWCs) technology is used to convert wave energy to electricity. OWCs are wave energy converting technologies that generate energy from the rise and fall of water caused by waves and tides in the ocean. These devices can be installed onshore preferably on rocky shores; nearshore in up to 10m of water; or offshore in 40-80m deep water. As water rises and falls around and inside an OWC, air is displaced by the water in a collecting chamber and pushed back and forth past a bidirectional turbine which converts the airflow into electricity. This bidirectional turbine always spins the same direction regardless of the direction of airflow, allowing for electrical energy to be continuously generated. Also, since the discrete protective casing of the public space (including the hull and ceiling of this space) is exposed to direct sunlight, it could be covered (at least partially) with solar panels to also benefit from solar energy and thereby enhance green power production. Here, the casing has been covered with glass to transmit light and provide vision.

Functionally, this roofed public space is designed to be flexible and multi-functional. The applicability of this space may vary depending on occasions and events along the year. For instance, the possibility of holding a fair or a particular festival has been well provided. In addition, the possibility of permanent creation of leisure centers in this part of the project such as restaurants, coffee shops, stores etc. has been taken into account. Therefore, people may come to this place for promenade, visiting the sea or they can even use this space as a terminal for recreational ferries.

**Environmental Impact Statement**

Oscillating Water Columns (OWCs) have shown promise as a renewable energy source with low environmental impact. A Life Cycle Assessment of OWC calculated that the carbon emissions over 25 years, including construction, installation, operation and decommissioning, would be 24 grams of carbon dioxide (Oceanlinx, 2012). In fact, OWCs have no moving parts in the water, and therefore pose little danger to sea life. The OWC itself will operate as an artificial reef to increase the marine species in an area.

The Tornado Tower can generate power at very low wind speed conditions. Traditional wind turbines produce aerodynamic noise by the rotation of the blades, which can create annoyance and interference in the quality of life of nearby residents. By eliminating the need for massive tower mounted rotors, the Tornado Tower significantly reduces the high energy and low frequency noise nuisance created by wind farms. Traditional wind farms represent a risk to birds due to collision with the rotating blades, interferences with migrations, and reduction or loss of habitat. However, the Tornado Tower thanks to the absence of rotating blades and its smaller land use, contributes to significantly reduce the negative impact on birds.

All the energy production and transformation components including those related to solar energy, wave energy and wind energy structures and equipments are inaccessible for the general public and are only open to specialists/engineers for [maintenance, repair, and operations.](https://en.wikipedia.org/wiki/Maintenance,_repair,_and_operations)This makes the whole project a safe installation. Moreover, regarding the fact that the Green Tornado Complex is designed such that it is able to harness clean energy from three different types of clean energy resources, namely wind energy, solar energy, and tidal energy, and noting that a combination of these resources is always available in Santa Monica Pier for a variety of weather conditions, different seasons, or various hours through a day, one may come to this conclusion that the proposed design is a very efficient and promising project which will be able to meet the energy needs of the beautiful City of Santa Monica.

**Conversion Efficiency**

The actual production plant of the OWCs is rated at 500 kW. The capacity of the employed OWCs is estimated at approximately 40%. Therefore, the amount of the electricity actually produced annually is 2,752,000 kWh using wave/tidal energy. Our design is also expected to be capable of generating 7,380,000 kWh annually through wind energy. Assuming a 30% capacity factor, and with a diameter of 50m, the considered set of heliostats would concentrate enough heat to produce 5,100,000 kWh annually. The total energy generated from our proposed design, i.e. 15,232,000 kWh, would be enough electricity to power the greater part of the City of Santa Monica.