Journal of Engineering Research

Volume 6
Issue 4 *(This is a Special Issue from Visions for Future Cities Innovations & Environmental Technologies Conference, (VFC2022), Cairo, Egypt, 24-25 September, 2022)*

Article 56

2022

The Search for a New Theory of Sustainable Architectural Design: Breathing Architecture

Tamer Tamer Anwer El Gabaly, Rasha Said Abd el-Lateef

Follow this and additional works at: https://digitalcommons.aaru.edu.jo/erjeng

Recommended Citation
Tamer Anwer El Gabaly, Rasha Said Abd el-Lateef, Tamer (2022) "The Search for a New Theory of Sustainable Architectural Design: Breathing Architecture," *Journal of Engineering Research*: Vol. 6: Iss. 4, Article 56.
Available at: https://digitalcommons.aaru.edu.jo/erjeng/vol6/iss4/56

This Article is brought to you for free and open access by Arab Journals Platform. It has been accepted for inclusion in Journal of Engineering Research by an authorized editor. The journal is hosted on Digital Commons, an Elsevier platform. For more information, please contact rakan@aaru.edu.jo, marah@aaru.edu.jo, u.murad@aaru.edu.jo.

Special Issue from: Visions for Future Cities: Innovations & Environmental Technologies Conference, (VFC2022), Cairo, Egypt, 24-25 September, 2022

The Search for a New Theory of Sustainable Architectural Design: Breathing Architecture

Tamer Anwer El Gabaly[1] , Rasha Said Abd el-Lateef[2]

[1]Faculty of Engineering - Ain Shams University, Egypt, drtamerelgabaly@gmail.com
[2]Faculty of Energy and Environmental Engineering, The British University in Egypt, rasha.said@bue.edu.eg

Abstract: **To maintain the reduction in fuel consumption and the need to modify the techniques concerning climate change new ideas for example "Parisian worker gardens", New York's "community gardens", and "vegetable squares" of Muscovite, come into the picture. The city aims to produce more clean energy than it consumes within fifteen years for a positive energetic assessment. The city plans to shift more towards renewable energies for example photovoltaic cells, biomass, green architecture such as walls and roofs, etc. The new architecture should also follow these green technologies and methods.**

- **Methodology—The methodology of this paper is based on a qualitative research format for findings and results, depending on:**
- **Data collection, Data Analysis, Theoretical analysis and analytical cases studies integrating the interdisciplinary fields of green technologies and sustainability.**
- **Thus producing a new language of architecture based on the dynamic relation among materials, structures and finally a new spatial idea. Empirical application and study. Besides rational comparisons and conclusions.**

***Keywords*: Bio towers, Algae, Biofuel, morphology**

I. INTRODUCTION

Green technology is the solution to avoid the recent climate change catastrophe. It demonstrates that when various ecological concepts are exploited as imagery sources, it increases both the communicative power and social relevance of architecture. The designing of urban architecture is adopted by the new ecological architecture, which utilizes the performance of the building structure as a guiding design principle. This new type of architecture prioritizes performance to provide an all-encompassing new method for designing the built environment by utilizing digital technologies for better performance-based simulations, both qualitatively and quantitatively. The notion of change in styles and designs of architecture has always been observed as the space perception develops throughout history from static to dynamic. [10].

Buildings become more active, spaces get more dynamic, and materials become lighter. Its geometry switches from Euclidean to non-Euclidean. Liquid architecture would use inertia instead of mass as its main component. Since it can express new ideas about dynamic space in a new architectural form, energy is the fundamental component of this new language. This era must be transformed by using new architectural scenarios. The transition from technology to ecology is significant. Our main issue is finding a way to make this concealed element visible as a brand-new reality and a contemporary building beginning for the new century. It is a brand-new structure that life and time have combined to create. It came into existence as an outcome of the union of biology, science and technology, and structure and architecture. It symbolizes the shift from typology to morphology [9].. The secret DNA code behind the new possibility in modern architecture is combining the genes of historical buildings with the genes of morphology [12].

Our main objective is to create an architecture that produces zero emissions to reshape this era and spark the argument between design and nature, abstraction and representation, and reason and intuition (Fig. 1). The building will be silently activated by green technologies and methodologies (Fig. 2) (Fig. 3).

Fig. 1. A Plea for a Green Architecture and Zero Emission Structures

Fig 2. A Plea for going green.

Vol. 6, No. 4, 2022 Journal of Engineering Research (ERJ)

Special Issue from: Visions for Future Cities: Innovations & Environmental Technologies Conference, (VFC2022), Cairo, Egypt, 24-25 September, 2022

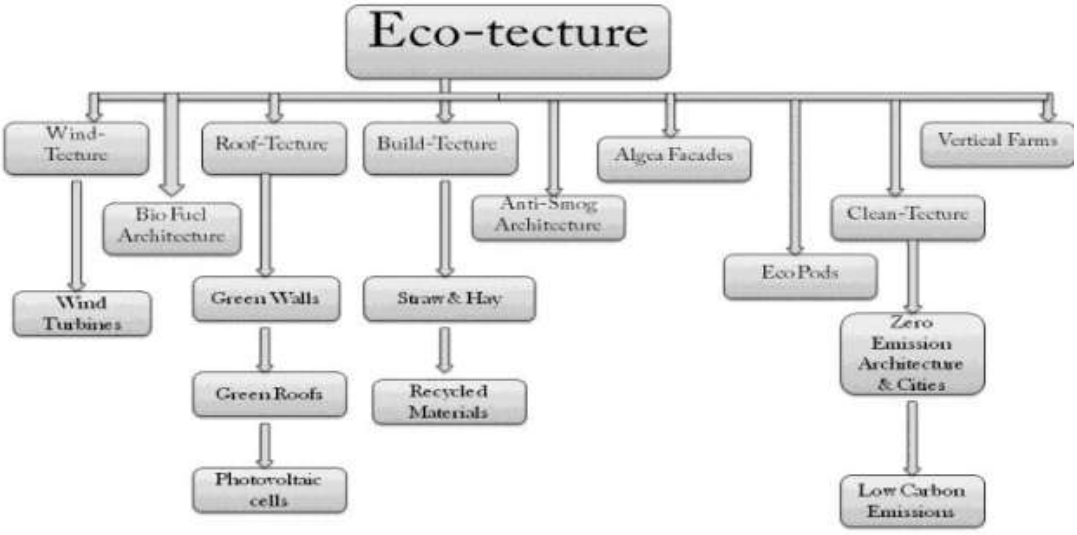

Fig. 3. Eco- tecture

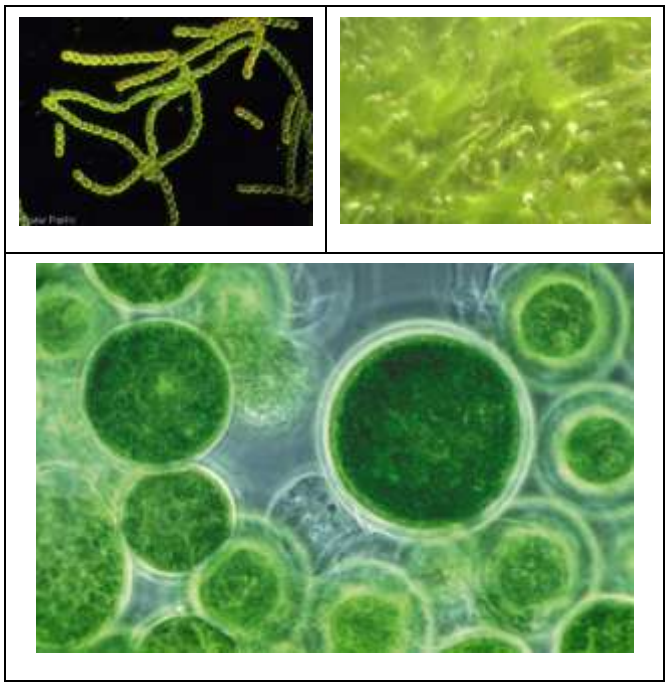

Fig. 4. Algae & Phytoplankton [11]

II. ALGAE BASED DESIGN TOWERS

Biofuel is currently a hot issue, and everything from agricultural waste to algae is considered a potential source of energy [6] (Fig. 4). As the saying goes, "Do not quit history but let it go." What if an entire structure served as a source of biofuel? Even though the concept is still mostly speculative, architects are jumping on board and creating amazing ideas for biofuel production facilities (Fig. 5). The Bio Tower is a collection of cactus-shaped towers that produce biofuel crops in various metropolitan locations. These towers are supposed to function as filters to enhance the quality of the air in cities.

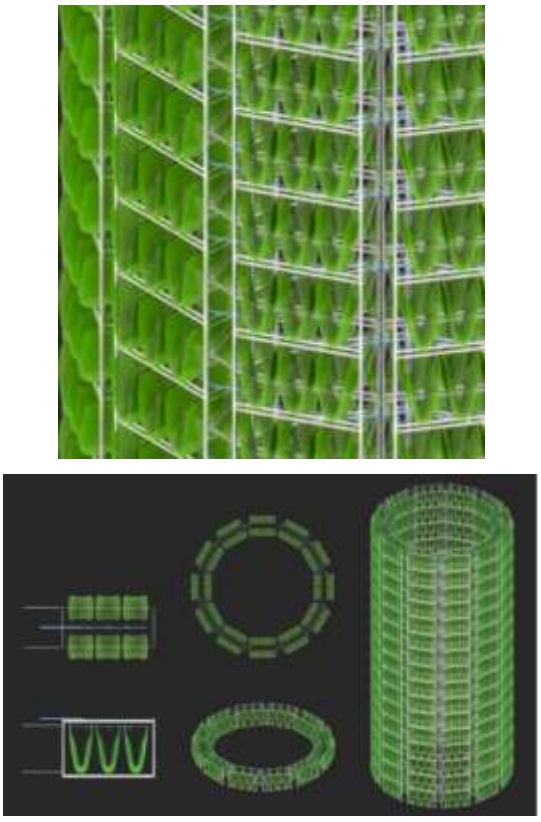

Fig. 5. Algae based design tower. [3]

A lot of sustainable technologies will be combined in one structure to make such a high-tech growth machine. [3] These technologies are all now in use, but they are not incorporated together in a single space. Enhanced efficiency, lower pollutants, and cut costs are all advantages of biofuels generating towers. The Bio Towers would also deliver fresh oxygen to smog-choked cities by functioning as filters and air healing processors, in addition to enhancing the architectural

form of the city layout. Renewable energy sources like the sun and wind will be used to create energy, while energy demand will be reduced by energy-efficient construction techniques. [7]

In a perfect scenario, the production of energy by the structure exceeds its needs and thus would return the remaining extra energy to the grid. These buildings will play a bigger role in supporting the enormous population as cities grow to accommodate the growing global population. The UN estimates that to feed the world's expanding population, we will need to produce 60 percent more food over the next 30 years. The emerging idea of vertical farming is one more intriguing area to search for further solutions. It is a novel strategy for addressing the demands of a crowded world with a finite food supply [8]. It suggests using a sky farm which can use a bio-gas plant that can create methane from the farm's waste, which can then be used to burn to produce its own power. Internalizing natural habitats into their biomorphic structure and supplying functionality, energy, and food tackles some of the drawbacks of green roofs. This is an innovative strategy for achieving feasible vertical density since there is a continuous increase in the world's population, and cities are subject to a continuous increase in demand for resources. Farms, homes, and marketplaces are located inside the biomorphic skyscraper, which was designed after the structure of plant cells. In addition to providing crowded metropolitan areas with CO2-absorbing green spaces, these organic buildings will integrate technologies like nutritional technology, regulated lighting, and CO2 levels to fulfil the future food requirements of the masses. [5]

The city environment is continually altered by this structure: "Through food production and consumption, this skyscraper sets up a fluctuation of varying densities and collections of people, bringing together different social and cultural groups, creating new and unforeseen urban experiences that form and dissipate within the flux of city life." Although some could protest that operating a farm like an industrialized factory is taking the farm too far away from nature, the idea offers too many advantages to be disregarded. [3]

Such handling of agriculture and the placement of farms closer to urban areas would be advantageous to both people and the environment. Meeting the demands of a crowded world with a finite food supply is the fundamental advantage of these novel approaches. At the start of this century, urban attention is shifting toward garden flats, which bring the countryside back to our congested cities. People are increasingly campaigning for communal urban agriculture, which may help make cities more resilient and rethink how we produce food. [5]

The concept of energy production serves as the inspiration behind the tower. Dynamic Energy is a representation of the Taiwanese people's seeming vitality and innovative optimism. The main components of this mechanism are the droplets. The pattern is resonant with their movement, presence, shape, and dynamics.

The citizens are welcome to observe the processes up close in a large portion of the tower. The everyday situation of food cultivation will be evident even from the elevators. There are numerous diverse plantation and regional environment setups throughout the tower. Its main function is to grow algae, which allows it to generate its electricity. It is a self-supporting building (Fig. 6).

When the algae are drenched and processed, it creates Biomass that can not only be served as food for plants and fishes but can also be used for the production of paper and can be converted into biofuel for engines. This process results in lower CO2 levels in the environment. A 10,000 M2 area of algae atop the tower generates 3,266,400 liters of oil and several thousand tons of Biomass annually. [2]

With stored income, a similar building might be improved even further to increase the amount of productive surface. The building is made out of a network of steel grids that spiral around the core of elevators. The droplets are membrane-skinned steel cages. There are three levels of observation:

1) The top observation level provides a view of the mountain.
2) The area of hydroponically grown vegetation at the mid-observation level allows the public to speculate on processes and plants.
3) The last levels include birdcages and aquariums. [12]

Fig. 6. Droplet Tower by Sir Peter Cook and Gavin Robotham. [14]

III. BIO FUEL TOWERS

As architecture becomes fluid, inertia instead of mass would be used as the main component. Since it can express new ideas about dynamic space in a unique building form, energy is thus, the fundamental component. This modern era must be reshaped by this new architectural concept. This, again, is a significant transition from technology to the ecological environment. Our main goal is to figure out ways to make this uncommon dimension into a vastly adopted reality and a whole new type of building for the next generation. It is a unique structure that has been shaped by time and life. It came into existence as an outcome of the union of biology, science and technology, and structure and architecture. It symbolizes the shift from typology to morphology. Our main objective to create an architecture that produces zero emissions to reshape this era sparked the argument between design and nature, abstraction and

representation, and reason and intuition. The building will be silently activated by green technologies and methodologies.

Energy will be produced using renewable energy sources such as the sun and wind, and energy-saving construction techniques will reduce the energy demand. In an ideal situation, the production of energy by the structure exceeds its needs and thus would return the remaining extra energy to the grid (Fig. 7).

Bio towers scattered throughout the city are biofuel crop-producing towers that produce bio crop, which is shaped like cactus. These towers are supposed to function as air filters to enhance the quality of the air in cities. Several green initiatives will be combined in one structure to make such a technologically advanced growth machine. Currently, these technologies are already active and in use, but not all of them have been integrated into a single place. Enhanced efficiency, lower pollutants, and lower transportation costs are all advantages of biofuel generating towers. The Bio Towers would also deliver fresh oxygen to smog-choked cities by functioning as filters and air healing processors, in addition to enhancing the architectural form of the city layout. [6]

Fig. 7. Bio fuel generation towers: Crop production Tower. [5]

A concept model of a 240m high skyscraper was developed by Czech architects “Pavlína Doležalová and Jan Sméka”. These are basically “living and breathing lungs” for a polluted city environment. A whirling structure known as a “City Respiration Skyscraper” is also developed to purify the polluted air of the urban environment through its “sea-sponge” and algae-covered architecture (Fig. 8). According to the architects, “this helicoidally structure acts as a chimney where warm and polluted air is captured at the bottom and filtered and oxygenated by the algae and a specialized water-sprayed-system.” A group of Metropolis Respiration Skyscrapers, designed to operate as a network, might perhaps clean a very polluted area in a relatively short time. The 240-meter-tall "City Respiration Skyscraper" was built by Czech architects Pavlina Dolealová and Jan Smékal to restore clean air to the major cities of the world by employing algae as a purifying material. It is planned to build the tower right in the middle of the heavily polluted districts. The pollutants and exhaust gases can easily be converted into pure air by a system of skyscrapers.

A 3D clustering of distinct concrete three-spike modules, modelled by sea sponges, makes up the skyscrapers outside the cellular structure. Hot and dirty air is drawn up from below in this chimney-like structure, where it is purified by the algae. Clean and oxygenated air is the ultimate product. [2]

IV. BIO PURIFICATION TOWERS OF TITANIUM DIOXIDE COATING

The next example of the air purification design sample is the Bio purification towers of titanium dioxide coating developed by Ted Givens and Benny Chow. [1] (Fig. 9)

The city environment was long polluted before the lighting of the first fire in LA, and even the first vehicles were operated in Shanghai. The tainted yellow glow of Beijing and southern California serves as a disturbing reflection of a dying environment. Simple balance is now insufficient. There must be a recalibration of bad and defective architectural technologies. We are interested in creating a structure that transcends itself and subverts larger-scale issues. One building can only have limited influence. To make a significant difference, a network structure is needed. The objective of such towers is to solve the polluted air issue in urban areas.

The tower operates by removing airborne dust, grease, and bacteria from the air and converting them into oxidizing materials and water. The titanium dioxide Nano-coating applied to the tower causes this reaction. This reaction is self-sustainable as sunlight during the day and UV light at night are the source of the power. Energy stored in PV panels during the day is the source behind these UV lights. The quantity of solar energy captured throughout the day will determine how bright the tower will appear at night. Contrary to the yellow haze during the day, the blue glow at night indicates the air purifying levels.

Fig. 8a. Algae Powered Skyscraper: City Respiration Skyscrapers [2]

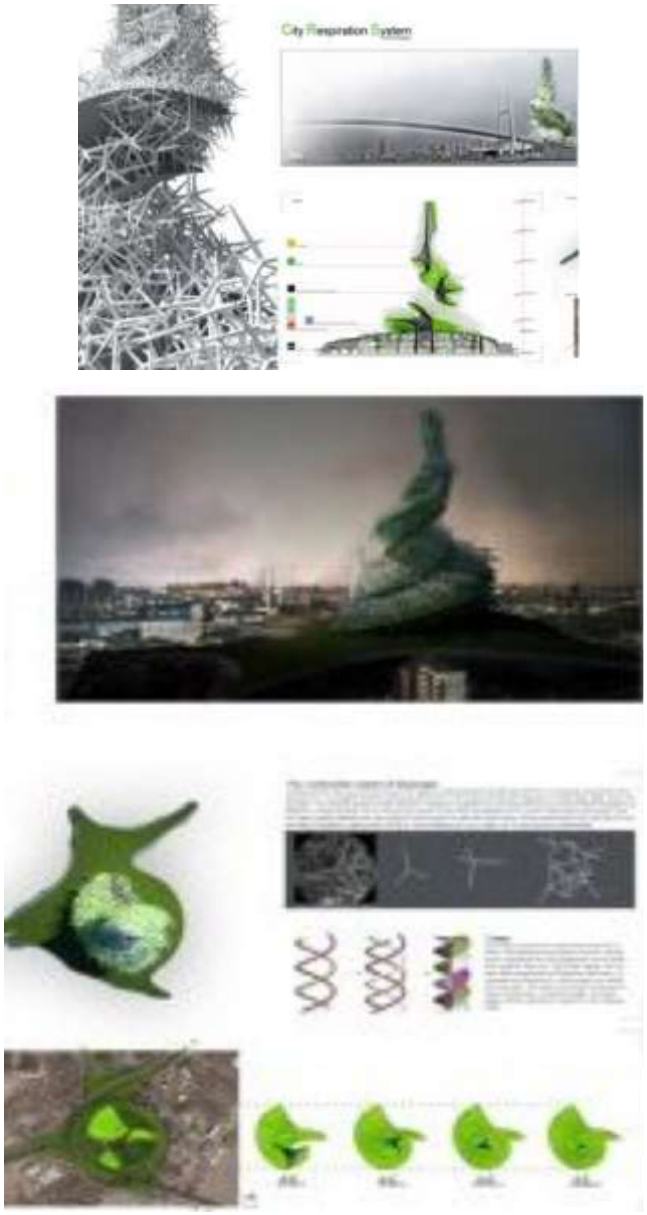

Fig. 8b. Algae Powered Skyscraper: City Respiration Skyscrapers[2]

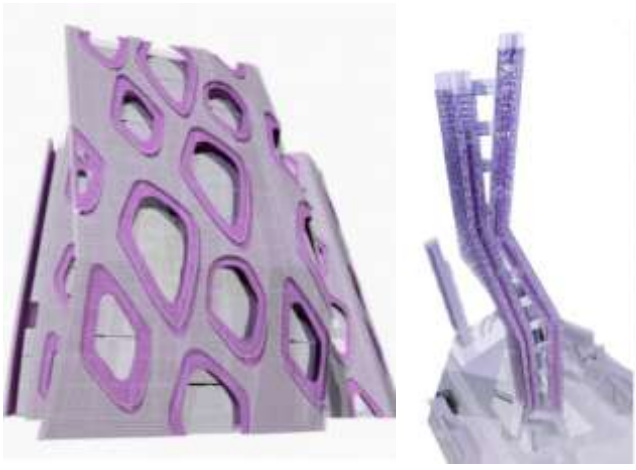

Fig. 9a. Bio-Purification Tower with Titanium Dioxide Facades. (Source: [1])

Fig. 9b. Bio-Purification Tower [1]

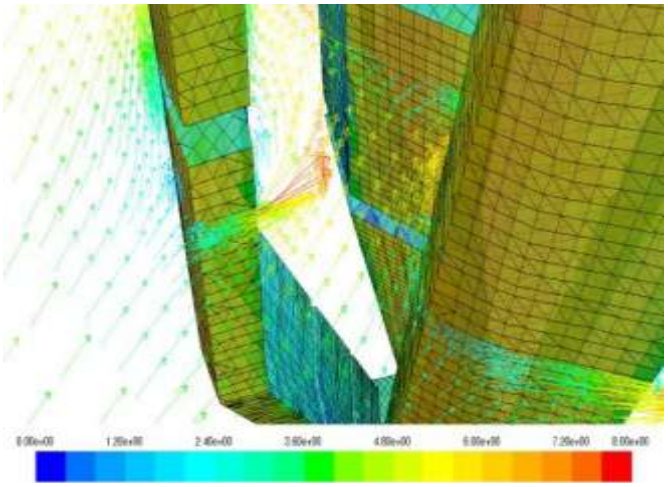

Fig. 9c. Bio-Purification Tower [1]

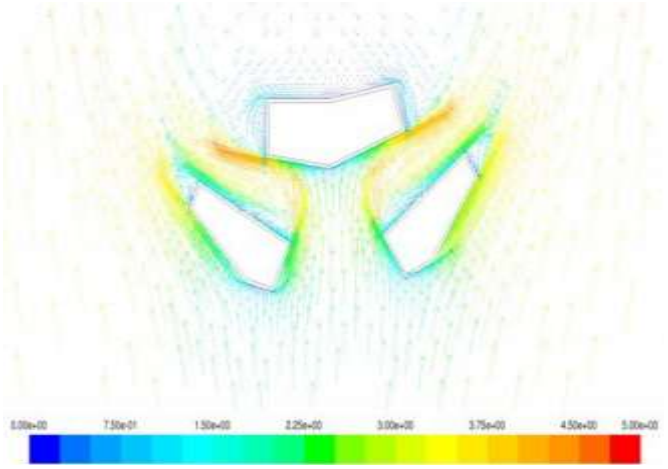

Fig. 9d. Bio-Purification Tower

Basic photovoltaic principles are employed to define the structured form of the tower, which is then magnified in size by a concentrated examination of wind and light. Several interconnected environmental factors trigger each step of the process. The extra technical advancement that titanium

dioxide offers adds to the benefits of passive solar design. By adding additional technical methods while keeping the technology as straightforward as possible, we prevent the pitfalls that come with technological issues.

The tower is divided into three parts for various reasons. Firstly, it enhances the surface area. Secondly, it is the source of southern light to each bar, and lastly, it increases the speed of the wind and controls its direction. The increased surface area enables us to clean a greater amount of air as it provides more area on the outer coverings of the tower on which the titanium dioxide can be applied. The increase in the wind speed and its focused direction served two purposes. It provides 1) power to multiple vertical wind turbines connected in series and 2) cross ventilation for individual rooms of every unit in the tower by pushing the air across the panels. The creation of positive pressure on the southern facades and the resulting negative pressure on the north towers results in an efficient cross ventilation process. On the bridge that connects the three towers, a series of wind turbines are placed. The direction and compression of airflow are controlled by the building structure to achieve maximum pressure on wind turbines. To help control the internal levels of humidity of the buildings, there are small gardens constructed inside the two-story bridges. There is a natural separation created to separate the living area from the resting area.

The north and south towers are constructed for each unit such that each unit can utilize the light and heat-gain potential to its maximum. A small amount of glazing is applied to the east and west towers to counteract the uncontrolled and low-angled light.

The segmented and cellular structure of the titanium dioxide molecule served as the inspiration for the skin design of the tower. The structure is covered with a network of organic cells that are angled to collect the water produced because of the skin's chemical reaction and to gather and gradually release rainwater. To create natural shading, the skin pulls out from the structure on the south towers. To maximize sunshine and give 50% covering to regulate the temperature during the cold season, it pushes towards the inner skin of the northern side of the structure. The skin additionally optimizes the building's exterior by floating off the structure to exclude UV radiation, but it can be dangerous for people having direct exposure.

Throughout the tower, several gardens are located. They not only serve as public spaces but also as wetlands which helps in collecting the water that is produced as the byproduct of the reaction. This series of gardens also serve in processing and filtering the contaminated water coming from the building. They also produce oxygen by using the CO2 produced due to skin reactions. The plants must contribute to preserving the initial net zero emissions. The treated water is finally collected in a sizable pool at the foot of the building, where it supports a substantial number of life forms such as plants and animals. Additionally, water is pumped from the pool back up the towers to supply the restrooms. The pool also serves as the heat sink for the “back-up air conditioning system” to minimize the “heat island effect” as the heat from the system is slowly released here since the pool is located at the base of the tower.

It is also suggested to incorporate self-cleaning bathroom tiles and windows, both of which have been on the market for over a decade. A "smart coating material" which is efficient enough to keep the surface clean by washing away any impurity or pollutant is what scientists have been working on as a solution, but it is insufficient for the current rapidly increasing urbanization. The most difficult problem is figuring out how to break down the molecules of pollutants like nitrogen oxides, which are mostly produced by heavy industry and car exhaust.

The increasing urbanization increases the risks of contagious diseases. It is preferred to use nanomaterial to eliminate and minimize the bacteria in the internal areas of towers. In times when increasing urbanization is leading to high infection rates, a "sanitized walk-off mat" is insufficient to avoid another global pandemic; instead, building that is self-sustainable in neutralizing the bacteria is the need of time. This is also proved by "SARS" and "H1N1".

Cross ventilation creates air streams that emerge from each unit, intending to distribute polluted air far away from the tower and avoid backflow in its neighboring areas. Scientists may now adapt and improve the coating technique on towers to incorporate "light-activated Nano-titanium dioxide," thanks to the development of today's nanotechnology. When exposed to sunlight or ultraviolet (UV) radiation, the "TiO2-based photo-catalysts” can start a string of chemical processes that result in the production of hydroxyl radicals. The photo-catalyst reaction will have the most power from the artificial near-UV light source. The majority of the air contaminants and pollutants, for example, "volatile organic compounds” or "nitrogen oxides," will be oxidized and degraded by these radicals. Even the elimination of bio-contamination can be helped by them. With the use of this technology, any surface may become mold- and bacterial-free. It can clean the air in our surroundings and shield our structures from bio aerosol pollution.

The developed structure targets maximizing the use of solar techniques along with efficiently taking advantage of TiO2 skin. This project is active in Qingdao, China. Greater profit generation will help attract more investors, which in turn helps to create more green energy and sustainable solutions. We think that once the world economy recovers, consumers will start seeking secure investments. Hopefully, it won't be difficult to decide whether to buy a residential unit with a pro-environment attitude or not. The progressive policy should be used to support such designs.

V. CONCLUSION

The twentieth century began with a flood of idealistic manifests from architects extolling the virtues of new building technologies to dematerialization and the loss of weight. Rarely did prophetic designers foresee the negative effects of industrialization. For the modernist pioneers, manufactured products were synonymous with liberty and unlimited opportunities. They never imagined the devastating consequences of these artefacts on global warming, declining resources, shrinking water supplies and overpopulation. A new scenario in architecture is required that has to reshape our time. It is a major shift from technology to ecology. It is a new

architecture, designed by life and shaped by time. Our task is a zero emission architecture raising the debate between architecture and nature. Smog eating architectural roofs presents a concrete architectural and urban proposal that entirely reconfigures, and consequently develops a new architecture. This new kind of architecture places broadly defined performance above form-making; it utilizes the digital technologies of quantitative and qualitative performance-based simulation to offer a comprehensive new approach to the design of the built environment. New forms of architecture and spatial structures, in addition to digital technologies is swiftly gaining in popularity and replacing the slab apartment buildings reminiscent of the "Hilbersheimer block that dominated the urban landscape over the past 40 years. Energy will be generated from renewable resources like the sun and wind, while energy efficient building technologies will minimize energy needs. This new typology uses building performance as a guiding design principle and adopting a new list of performance-based priorities for the design of cities, buildings, landscapes and infrastructures. This new kind of architecture places broadly defined performance above form-making; it utilizes the digital technologies of quantitative and qualitative performance-based simulation to offer a comprehensive new approach to the design of the built environment.

REFERENCES

[1] Admin. (13 August 2010). *Indigo Bio-Purification Tower with Titanium Dioxide Facade*. https://www.evolo.us/indigo-bio-purification-tower-with-titanium-dioxide-facade/
[2] Admin. (25 JUNE 2010). *Algae-Powered Skyscraper Filters Air in Polluted Cities*. https://www.evolo.us/algae-powered-skyscraper-filters-air-in-polluted-cities/
[3] Castle,H. (2011). *Experimental Green Strategies*. London: Wiley.
[4] Dan. (25 October 2009). *Giant Cactus-Shaped Biofuel Towers – Biooctanic*. https://www.archtopia.com/giant-cactus-shaped-biofuel-towers-biooctanic/
[5] La Roche, P. M. (2016). *Carbon-Neutral Architectural Design*. Boca Raton : CRC.
[6] Mahapatra, S. (30 December 2021). *Biofuels and their sources of production: A review on cleaner sustainable alternative against conventional fuel, in the framework of the food and energy nexus*. Energy Nexus (Vol 4). P-p . https://doi.org/10.1016/j.nexus.2021.100036
[7] Nageswara-Ra, M.(2018), *Advances in Biofuels and Bioenergy*. London: BoD
[8]Eisenschmidt, A.(2019). *The Good Metropolis: From Urban Formlessness to Metropolitan Architecture*. Basel: Birkhauser.
[9] Pearce,P.J. *Principles Of Morphology And The Future Of Architecture*. International Journal of Space structure (Vol 11, Issue 1-2). https://doi.org/10.1177/026635119601-217
[10] Rovira, S.(2021). *Digital technologies for a new future*. Santiago: United Nations Publications.
[11] Schaechter,M. (2009). *Encyclopedia of Microbiology(3rd ed).* San Diego: San Diego State University.
[12] Sero,E. T.(05 February 2020). *Biophotonics for improving algal photobioreactor performance: A review*. Energy Research (Vol 44-Issue 7), Pages 5071-5092. https://doi.org/10.1002/er.5059
[13] Owen, T.(2014). *Liquid Architecture*. New York: Architect Publications.
[14] Warmann, C. (28 November 2010). *The Tower of Droplets by Sir Peter Cook and Gavin Robotham*. https://www.dezeen.com/2010/11/28/the-tower-of-droplets-by-sir-peter-cook-and-gavin-robotham/