ENERGY - PLUS DOWNTOWN

ALESSANDRO MELIS, PENGFEI LI, SHIVANI KHANNA

National Institute of Creative Arts and Industries (N.I.C.A.I.), University of Auckland
School of Planning and Architecture, Building 421, 26 Symonds Street, Auckland

ABSTRACT

The climate crisis will be the main driver of social pressure in the next twenty years, and the production of food is the biggest single component of CO_2 emissions (today already one billion of seven billion people are malnourished).
In New Zealand the climatic condition, food production and the residential density are extremely favourable which will therefore represent a perfect case study in which to test new sustainable urban strategies.
In view of increase of global population by at-least two billion by 2050, it is essential to safeguard the availability of soil for sustainable food production.
Increasing the housing density in already urbanized areas and making them energy self-sufficient is an absolute need in this hour.
One of the strategies that can guarantee results, in short term, is retrofitting of the downtown buildings' fabric through "Energy-Plus" interventions, thus transforming urban districts into power generators.
The present study provides possible solutions and applications of this approach in Auckland City Central through sampling of some districts, in order to analyse results for power generation, and overall benefits of comfort, reduction of Heat Island Effect and seismic response of buildings.

KEYWORDS AND KEY-TERMS:

Energy-Plus; Building Fabric; Integrated Double Envelope; Solar Gallery; Hydroponic Plant cultivation Media

INTRODUCTION: REASON FOR TRANSFORMING DOWNTOWN BUILDINGS' FABRICS

Professionals and scientists around the world are increasingly apprehensive since the 1970's when it was established that the consistently increasing concentration of green house gases would lead to climatic change destabilising the planet's natural conditions as presently known. Global warming is the effect caused due to continuous warming of the Earth's atmosphere causing a consistent rise of average temperature resulting in grave changes in the climate system (Refer Weart, 2008). Data from U.S. Energy Information Administration (Refer www.eia.gov) and other climate observatories around the world have revealed that burning of fossil fuels at the current rate which is right now plentiful and supposedly cheap, is enough to push the planet to 450 ppm (parts per million) of CO_2 in the atmosphere.[1] Attaining this limit would trigger a chain of potentially irreversible events of climate change, glacial melting and rise in sea level (Refer Inter- governmental Panel on Climate Change- I.P.C.C by U.N.).
Since the 1990's the Earth's atmosphere has experienced an increase of average global temperature by 0.7°C. By 2050 a further rise of 1°C and an increase of 2°C by 2100 (from 1990) is expected (refer- mfe.gov.nz). In another record by Al Gore (2013, pg 294) in his book 'The Future', it is mentioned, "*In 2012, new World Bank President Jim Yong Kim released a study showing temperatures will likely rise by 4 degrees C (7.2 degrees F), without bolder steps to reduce CO_2 and that there is no certainty that adaptation to a 4degree world is possible*." As is obvious, the future awaits us with warmer and more uncomfortable conditions for life habitation.
Higher temperatures and a warmer atmosphere would lead to melting ice caps and increase of average sea levels resulting in two other disruptive phenomena, natural stringency and reduction of soil area to build on. Future predictions by experts reveal a global sea level rise from 18 to 59 cm (Refer National Geographic) which would lead to chaos and destruction, besides putting out a then estimated population of nine billion

[1] Scientists are forewarning that at approx. 450 ppm CO_2 in the atmosphere, will trigger potentially irreversible glacial melt and sea level rise "out of humanity's control". We are currently at 398 ppm (february, 2013- refer www.co2now.org), and are increasing atmospheric concentrations of CO_2 at an unexpected rate.

people to run into acute shortage of habitable land (Foley, Ramankutty et al, 2011). Also, the extent and extremity of catastrophic natural events would be a devastating state of affairs (www.unfccc.int).
Clearly as discussed, at this rate we today stand in grave danger to prevent an observable fact which is a threat to the existence of life and Earth. Before looking at the solutions that can impede further deterioration of the situation, it is important to speculate on what has caused global warming.
The primary reason for global warming is release of high concentrations of Green House Gases namely Carbon dioxide (besides Nitrous oxide, Chloro Fluoro Carbons, etc) resulting in heat being trapped which roots the occurrence of the Green House Effect (Refer I.PC.C.). Further on, there are three crucial causes of increase of Carbon dioxide levels:

- Deforestation: cutting down of dense forest areas for using timber as fuel, in construction or in industries (such as paper manufacturing) or for continuing them as plantations that release lower oxygen levels compared to forest cover.
- Food Production: Foley and his co-authors (2011) while writing 'Solutions for a Cultivated Planet' have highlighted that high levels of emissions are also due to an elongated chain of post harvest processing and transportation of food resources.
- Burning of Non- renewable fuel: releasing harmful, toxic and green house gases by burning coal and petroleum to generate electricity or as transport fuel. In New Zealand, it has been documented that of the 71 MJ energy generated per annum, 35- 40% is utilised by buildings (refer- mfe.gov.nz).

  Elaborating that, commercial buildings spend up to 60% energy in trying to maintain optimum indoor habitable temperatures (refer- mfe.gov.nz). In a publication by the International Energy Agency (I.E.A., 2013, pg. 117), the writers mention that "*Building envelopes comprise of a range of (read: envelope) elements, with roofs, walls, windows, foundations and air leakage being the primary elements that affect building heating, cooling and ventilation loads. With over a third of global energy used to make buildings comfortable for occupants, advanced building envelopes will be essential to reduce energy consumption*".

It is thus evident that the Urban building sector in New Zealand and elsewhere, is consuming high levels of energy, that eventually results in Carbon emissions and Global Warming, by mechanically trying to heat or cool the building.
The solution is straightforward; to have better designed building fabrics, that are able to generate energy as well as allow the building to consume lesser electrical energy and limit the CO_2 emissions by exhausting lesser non-renewable and polluting resources.
This research aims to identify the energy generation potential of the Auckland CBD. The strategies examined mainly concern retrofitting of the existing high- rises and the open parking lots within the highest dense district of the city. High-rise buildings, on average characterized by low performing envelopes, and heat islands like the frequent large parking areas, can instead contribute to a better New Zealand through a new strategic design for energy generation, improving outdoor and indoor comfort and by introducing to cultivate local food produce on current urban unproductive surfaces. Giving the buildings a second skin would enable them to perform consistently both as a passive and an active device. Where appropriate, the external skin can contribute agriculturally. Power plants and green houses can be located to cover open parking spaces. This would considerably reduce dioxide emissions by lowering consumption of non-renewable, polluting natural resources, increasing local food production, and the energy generation from renewable sources. At the same time the strategy ensures high standards of comfort both inside and outside the buildings. The preceding discussion demonstrates the strong and influential relation between designing a plus-energy building fabric and the global warming phenomenon.

General Review of Green Building Rating systems on Energy performance of the Building Fabric

In the last 2 decades various agencies and councils have emerged to legitimise, audit and evaluate building designs to categorise them as 'Green or Sustainable' designs. Author Lemieux in 2004 publication states that "*the building envelope accounts for up to 80% of litigation in the construction process, it is therefore, necessary in the present times for Green Building Councils to develop guidelines that shall help the building industry design innovative and sustainable exterior envelopes*". Hence, it is necessary to review the significance allotted to energy efficient design of the building fabric by various green building rating systems.
Following is a review of a research conducted on this topic by a research student at the University of Auckland (Khanna, 2014, pg 47-50):

- LEED allots up to 39% of its credits' weightage towards designing a sustainable building envelope. Also, almost 8% of the total credits are dedicated towards an energy-plus building fabric design.
- BREEAM allows 55% of total credits to impact a sustainable fabric design. On the other hand, allows 14% of total credits to direct the design of the building fabric to be energy efficient.
- NZGBC the local New Zealand green rating system allows 48% of total credits to influence the design of building fabric as sustainable and 14.5% credits to direct the design to be energy efficient.
- The Living Building Challenge or LBC does not have a credit or point rating system. However, 2 of its 20 petals' intents strictly impose the building fabric to contribute to the plus- energy concept. The two petals/ intents are Net-Zero energy and Urban Agriculture. This can involve the building fabric to generate electricity for site use. This is the only system that directly emphasises the need for urban agriculture, that in an urban context like the Auckland downtown can only be practiced on building envelopes due to shortage of ground soil area.

These percentages highlight the significance devoted by some of the popular green building rating systems and that they can without doubt assist the architects and designers to accomplish a building fabric design that is energy efficient and contributes to the 'plus' factor.

ENERGY-PLUS SOLUTION 1: INTEGRATED DOUBLE ENVELOPE SYSTEM

Authors Harrison and Boake (2003) in their book Techtonics of the Environmental Skin define a double Envelope as *“essentially a pair of glass “skins” separated by an air corridor. The main layer of glass is usually insulating. The air space between the layers of glass acts as insulation against temperature extremes, winds, and sound. Sun-shading devices are often located between the two skins. All elements can be arranged differently into numbers of permutations and combinations of both solid and diaphanous membranes”.* Hence, the following definite characteristics of a Double Envelope System are gathered: an interior skin layer, an exterior skin layer (in this case an energy generating and conserving facade system), a cavity of appropriate dimensions between the two skins, openable panels strategically placed on both skins to allow appropriate ventilation as per requirement and climate, detailed integrated ventilation system to naturally or mechanically control pressure zones and induce wind currents. As per current requirements, it is evident that the exterior skin of the integrated envelope must be highly efficient in character. To result in an energy- plus solution, it is necessary for the exterior skin to be equipped with energy generating elements like photovoltaic panels and comprehensive equipment like sensors and automatic control systems that operate the sustainable and an almost intelligent facade system in an efficient manner.

Classification of Double Envelope Systems

Double envelopes are classified under many criteria. The differences between each type under every criteria is significant to understand in order to implement at the design level.

Criteria A: On the basis of type of ventilation method:

1. Natural Ventilation: this relies on stack effect and pressure differences for air movement. E.g. The Building Research Establishment Building in Garston, U.K which has smaller shaded fenestrations creating pressure differences and wind movements. Internal vertical tunnels open on the top of the envelope as visible functional elements.
2. Mechanical Ventilation: implementing mechanical systems to enable exchange of air. E.g. The G.S.W. Office block by Sauerbruch Hutton Architects, in Berlin.
3. Hybrid Ventilation: or mixed-mode is a combination of natural and mechanical ventilation methods. This type requires a complex, centralized environmental management system that switches the façade’s components from natural mode to mechanical mode depending on climate and user need.. E.g. Minerva Tower Building, London.

Criteria B: On the basis of mode of ventilation (Refer Barkumme, 2007):

1. Outdoor Air Curtain
2. Indoor Air Curtain
3. Air supply
4. Air exhaust
5. Buffer zone

Energy Generating- Examples of Advanced Integrated Double Building Envelopes

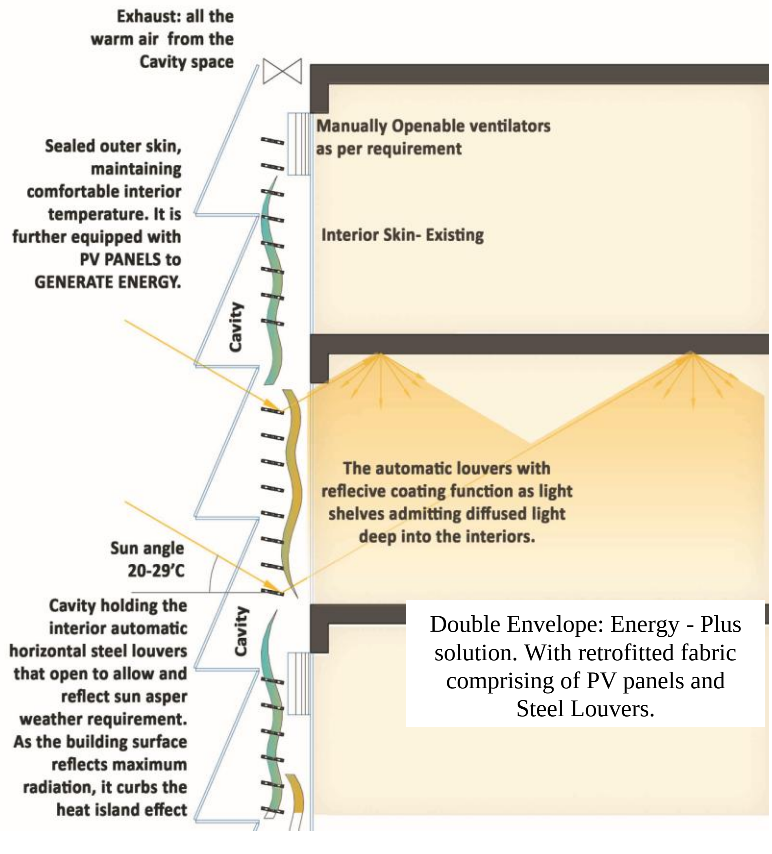
- Photovoltaic cell exterior: to harvest Solar energy
  Panels can be used on roofs and or mounted as curtain glass walls. e.g. GENyO, Center for Genomic and Oncology Research, Granada, Spain has a Photovoltaic second skin. The facade is responsible for generating 31,837 KWh/ yr of energy. This prevents 21.33 ton of CO_2 from being emitted into the atmosphere (Refer: www.onyxsolar.com).
- Wind energy exterior
  Wind turbines are used to harvest wind energy. High rise buildings in coastal areas are appropriate for placing wind turbines that can catch wind at the correct speed. A famous example of such a building is the Bahrain World Trade Centre by Atkins Architects which is able to generate 11% to 15% of its total energy requirement. However, the current technology has been able to provide for a finer solution. The designers are attempting to integrate smaller wind turbines with the exterior of an aero- dynamically shaped building. The shape and turns of the exterior skin channel to amplify the flow of the winds towards the turbines.
- Combined Systems
  Multiple combinations of two or more systems can be implemented so as to create a system that suits the building design as per location and climate. The possibilities and types of these combinations are many, although this paper shall limit to describing only the following:

a) Bio- mimetic and Dynamic skin system: the skin structure is mostly dependant on intelligence based dynamic systems that responds to climatic variations. Example is the Abu Dhabi Investment Council Headquarters Tower, or Al Bahr by Aedas Architects.
b) Bio- mimetic and Phase changing materials: in a recent advent labelled 'Metal that Breathes', biologist turned architect Doris Kim Sung unveiled her research on thermobimetals, a smart material made of thin metals that change their shape with change in temperature.

Retrofitting and Designing Double Layered Building Fabrics for Energy-Plus Solutions

For testing purposes, models were generated similar to the building fabric of popular downtown building, Fay Richwhite, on Queens Street in Auckland, that has a typical glazed facade. The fully glazed building was implemented with a possible retrofitting strategy by adding an exterior layer to the existing envelope skin. The result of implementing the strategy can be noted by the phenomenal display of energy efficiency of the buildings. The double layered fabric demonstrates the following positive results:

- The basic requirement of energy is substantially decreased due to the implementation of an integrated double skin system. The intermediate buffer works as an effective insulation in winter and a pressurized air channel allowing air to flow at high speeds due to strategic location of fenestrations in summer.
- On implementing energy generating PV panels on the sun facing building facades, the building is able to produce sufficient energy to support its own, now decreased, requirement, and in some cases, be able to feed back surplus to the city lines. Strategically north oriented PV panels in Auckland climate can generate energy of up-to 100-125 kwh/ m^2 per annum (Byrd, 2013,

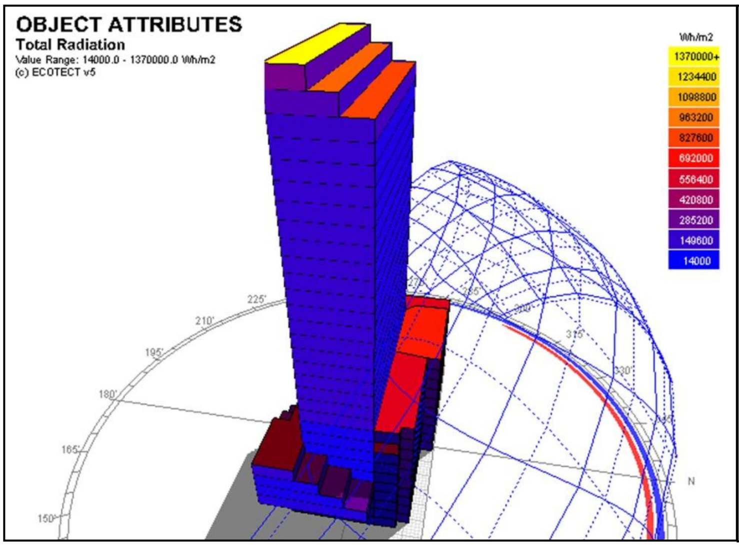


Double Envelope: Energy - Plus solution. With retrofitted fabric comprising of PV panels and Steel Louvers.

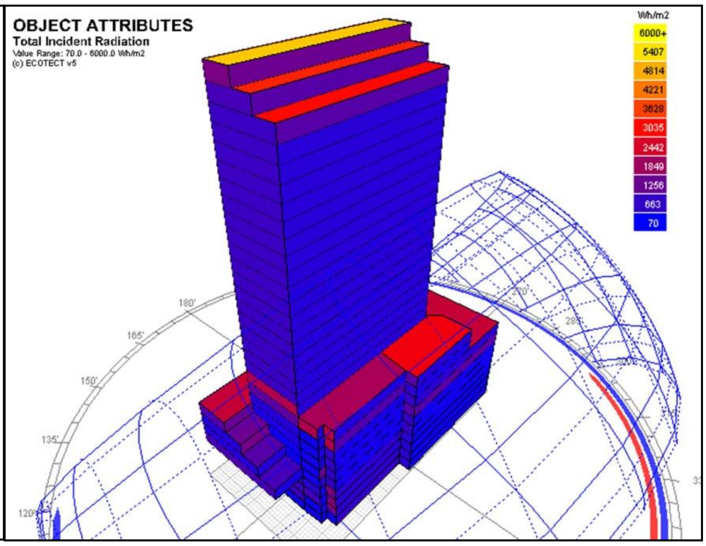
pg 92). A conventional 30 floor building in Auckland downtown, if equipped with appropriately oriented PV systems along an elevational and roof area of 6500sq.m., can generate an average of 650Mwh/ per annum of electricity (as tested on the simulated model's north-east to north- west facades only). As one can see the tabulated energy requirements of the building, this satisfies more than the general energy requirements of the building when retrofitted with a double fabric. Thus, the retrofitted downtown building holds the potential to generate annually a minimum of 20Mwh of sur-PLUS ENERGY for the city.

- Lastly, around the world, no city of any country is equipped with buildings that will survive through the expected climate change due to global warming. Keeping in mind the future, it is possible for Auckland to integrate its buildings with systems that can counteract the effect of soaring temperatures that would lead to a surge in energy demand throughout urban metropolitan centres across the globe. An integrated double envelope is a solution, as it is observed that with rise in temperatures due to climate change, the retrofitted building would perform even better and more efficiently. Adding a second energy generating skin to existing building facades is not only beneficial for reducing carbon emissions at present, but is a long term effective solution with due course of time and climate change.

The proposed model was tested on a validated parametric design software, Autodesk Ecotect to achieve the energy requirements of the building before and after the implementation of the double envelope strategy. A third model was also tested under presumed weather conditions that would prevail in Auckland 100 years from now as per the predicted climate change due to global warming. Following are the results of the simulations:



Total radiation absorption by EXISTING BUILDING FABRIC. note the range is between 14 to 1370 kwh/m^2. Derived from: Autodesk Ecotect Analysis Software



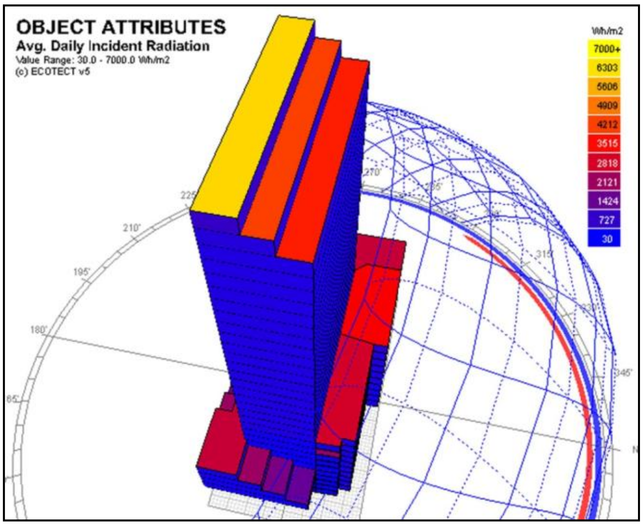
Total radiation absorption by the NEW DOUBLE ENVELOPE OF THE BUILDING (2114). note the range is between 0.03 to 7 kwh/m^2. Derived from: Autodesk Ecotect

Note that with the implementation of this strategy the radiation absorption of the building fabric is significantly decreased as the fabric becomes thicker with more insulated cavity and has an increased thermal mass. Based on this, the software also calculated the figures for energy required to maintain the internal temperature equilibrium. This also is significantly decreased as the energy required to cool or heat the building mechanically is very low.

Also, as was discussed, introduction of an integrated PV system on the exterior skin of the double envelope would lead to an Energy-plus solution, as enough energy would be generated in order to suffice the retrofitted building's requirement and return the surplus to city lines.

Surface area of PV paneled facade (of 30 floor test model) = 6500 sq.m.

Electricity generated by 1sq.m. of north oriented PV panel= 100-125kwh/annum (Byrd, 2013, pg 92)



Total radiation absorption by the NEW DOUBLE ENVELOPE OF THE BUILDING (2014). note the range is between 0.07 to 6 kwh/m^2. Derived from: Autodesk Ecotect

Total Energy/ annum= 6500x(100 or 125)= 65,000kwh or 650Mwh/annum

	Total radiation absorption through the facades (kwh/m^2)	**Heat gain and loss percentage due to composition of the envelope**	**Annual consumption of energy (kwh)**	**Annual consumption of energy per unit area (kwh/m^2)**
Existing single glazed model (Calculated and matched to actual consumption data)	14-1370	84.3%	110434.6	498.6
Integrated second skin 2014	0.07-6	68.3%	630848.7	284.8
Integrated second skin 2114	0.03-7	59.9%	600881.3	271.2

(all data and calculated values have been tabulated as per the analysis of the model building carried out on Autodesk Ecotect Software)

ENERGY-PLUS SOLUTION 2: INTEGRATED PHOTOVOLTAIC SOLAR GALLERIES

Power plant green-houses

The energetic green house is a sustainable and temporary architecture solution for open spaces e.g. surface parking lots in Auckland CBD for areas in the range of 750 sq.m. (e.g. 50x15 sq.m. open spaces). It combines the advantages gained from the power generation through systems based on renewable energy such as solar installations with the liabilities of the construction, creating a system that interacts with the surrounding responding to specific site characteristics such as the direction and intensity of sun exposure and wind velocities.

The idea of the project is based on the significant relationship between architectural form and energy efficiency, the two aspects complement each other and define the essential combination for buildings of the future. The intriguing geometry and specific technological choices that characterize the design are derived from an intense evaluation process following a precise hierarchical analyzing method:

- The reduction of energy consumption through modeling
- The optimization of energy generation and plating system
- The production of energy from renewable sources

The goal of the research is to create an installation that generates an optimal microclimate for performance of various activities, including that of food production. The system works within the buffer space in relationship with climatic context and is controlled by the shape and planting components. The materials used for construction are 100% recyclable.

The project also aims to ensure social sustainability, setting up the structure as a multi-functional element. The particular form of the glazed skin is derived from studying the site and environmental features (sun orientation and prevailing winds) for which the form acquires a sculptural value. As each site is different, so is every proposed form, individualizing each building from another and adding sculptural aesthetics to the overall district.

The project looks to contribute towards economic sustainability, beside the energy generation. The standardization of the elements that make up the glass structure allows ease of production and speed in the implementation. This construction system can be designed to be "scalable", thus as per requirements, it is possible to increase or reduce the extent of the structure. The remarkable performance and the ability to fully recycle the materials make the investment considerably profitable and sustainable overtime.

Energy analysis

The Energy analysis has been conducted on the basis of climate data (Auckland microclimate) i.e. the average solar radiation per annum, wind velocity, temperatures and air humidity. The technology is designed to wrap focuses on the realization of a skin that works as passive cooling machine whose special structure allows an aerodynamic shape. The complex form is obtained by successive refinements through software simulations taking climatic data for a specific geographic area as input that are returned with parametric-geometric responses. Hence it is possible to provide a specific form to the varying architectural and site contexts as per location. The particular climate data (Solar radiation mesh and wind flow diagrams) and analyzing parameters dictate the software simulation. Upon assessment, the resultant polygonal faceted form is obtained giving respect to each position and orientation. The result is able to maximize solar gains on the PV surface.

Optimization of the shape - Fluid dynamics analysis

The form is modeled as per the numerical simulations carried out by parametric software. The result is an aerodynamic structure that is able to accommodate the cold, and the prevailing winds by sliding them onto the outer surface, avoiding frontal impacts that would cause excessive cooling of the gallery. The pavilion is shaped and oriented to take advantage of the winds sliding above the glass skin so as to trigger a "natural draft" by creating pressure channels, when the covering panels, located in the right positions, are open.
A similar pressure difference draws exhaust air to the interiors, through special nozzles, thus ensuring flow of natural air into the interiors. The quality of comfort is particularly effective for the central areas of the tunnel, especially if it is made with a number of modules equal to or greater than 3, as in these areas there will be more static air, compared to the exterior 'open' head zones.
The fluid dynamic analysis of the shape (Computational Fluid Dynamic Analysis) takes place through the mesh settings of the analysis surfaces which are returned as vector values and chromatic behavior of the wind, with a precision of 0.001m, which is representative of the glass envelope.
The model is represented in uniform configuration, free of junctions or elements between panels that make up the surface as each junction would be appropriately sealed.
The analysis tests have been made through a horizontal plane (located at a height of 1.50 m from the floor) and a vertical plane (all sections have been verified at each vertical interval of 1.00 m). The wind was calculated with a speed of 10m/ second.
On conducting Vector analysis of multiple positions on planes, the output demonstrates how the various sections representing the fluid do not cause any turbulence or downdraft in correspondence to vertical surfaces. This demonstrates the effectiveness of the form in assisting movement of winds in the area of analysis, as they are designed as obstructive vertical surfaces but are inclined to behave aerodynamically effective.

Energy generation

The structure of the gallery is made of glass portals created by the Travi Vitree Tensegrity (TVT) building system (based on Glass Tensegrity Beams conceived and licensed by Prof. M. Froli, University of Pisa and Ing. G. Masiello). The building envelope is a power generator and is equipped with integrated photovoltaic cells on the exterior, containing a buffer space within, for the realization of passive environments. The geometric shape is designed to not just improve, but to maximize both energy generation and indoor comfort. The inclinations of the faces allow larger surfaces of PV elements to be oriented towards the sun-path, regardless of the climatic context and location of the gallery.
This enables the structure to obtain maximum yield for the duration of sun exposure on at least one portion of the PV surfaces, while the remaining part will integrate the generation with lesser yield. This results in total generation in each case, to be sufficient for the energy requirements of the gallery and also feed any excess energy into the city grid.
The project includes the use of thin-film photovoltaics, the sticker type that will be placed in between glass panels. In the resultant tests, yellow areas indicate better PV performance, the orange shows the areas with openable glass modules for natural ventilation, and the grey facades, are areas with lower generation power (these lower generating areas have not been taken in to consideration in the test model calculation). The arrangement of photovoltaic cells is studied to develop an adequate solar shield, ensuring shading during the hottest hours of the summer season. Stratified glass is also included, partly alongside the cells obtaining opaque panels and in part by creating a sunscreen system by placing cells like a "chessboard" on panels, obtaining shading of 50% of the concerned areas. The "thin film" PV is monolithic, and does not require the assembly of multiple cells as in the case of crystalline silicon panels. The material appears to have a lower yield than the equivalent monocrystalline but, having considerably lower amount of semiconductor compared to standard cells, the generation cost will be lower as well.

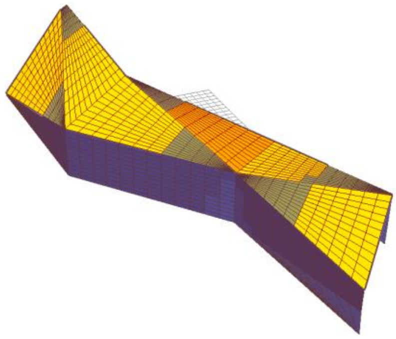
Calculation

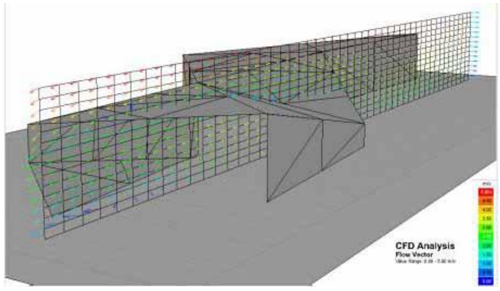
The parameters taken into consideration for the 750 sq.m. open site (dimensions 50x15 sq.m.) are:
- thin-film panels: Power between 77.5 and 87.5 Wp, generic shape of size=120x60cm, thickness=0.6cm;

- Of the total facade surface, area appropriately oriented for maximum solar gains: 50 % of 835sqm=415sqm;
- estimated power: (1,2x0,6) = 0.72 sqm generating 77.5 Wp;

(415x77,5) / 0.72 = 44'670, 14 Wp => 44.67 kWp (49.14 kWh / year);

Net energy consumption for eventual use of the gallery (greenhouse) is lesser than the energy generated. Hence, the building will be able to provide to the surrounding buildings and infrastructure. The selected photovoltaic technology, with integration of the cells in the glass layer, will contribute to the reduction of maintenance costs, as the PV would remain protected by the outermost layer of glass. Maintenance will also be facilitated by the modular nature of the paneled construction system, which is possible to be dismantled and reassembled.





The model undergoing software simulations and extensive evaluation for energy generation performance

Perspective Artist Impression of the software simulated model

ENERGY-PLUS SOLUTION 3: INTEGRATING STRUCTURAL STABILISING STRATEGIES WITH URBAN AGRICULTURE AND SOLAR ENERGY GENERATION STRATEGIES

Egbelakin and colleagues (2011) found that the investment on traditional seismic retrofitting of the Earthquake Prone Buildings could not make contributions to promote the buildings' ability of competition in marketing because the investment could hardly be paid back. Seismic retrofitting is the protection of structure from an unpredictable earthquake in the uncertain future; as a result, the added retrofitting may reduce the existing building's ability to resist or reduce the damage due to seismic disasters, the system however, does not bring about benefits until buildings are under threat. In other words, the investment can be effective only when the seismic structure works against natural possibly destructive forces. This makes it seem like a dead investment for building owners as there is no surety of returns or benefits of this expense. To a large extent, building owners and investors consider seismic retrofitting of buildings economically and financially unviable. In the absence of a sound structural design, the threat of earthquake disasters continues to loom over majority of the high-rise structures in metropolitan downtown areas where urban density is high and impacts can be extreme. Approximately 92% of the Earthquake Prone Buildings' owners never get any financial payback from their investment on seismic retrofittings (Egbelakin et al., 2011).
In this scenario, a solution proposal can be made to externally retrofit building fabrics. By adding a second stronger exoskeleton over the existing fragile envelope, the building can be made structurally sound and safe. The system can also be experimented with to implement as a Design- Plus solution.

Seismic strengthening by Fabric Retrofitting

Building fabric retrofitting for seismic strengthening optimizes the building's ventilation and heat distribution efficiency without reducing the quality of natural light in the interior spaces. It is a type of integrated double envelope system and hence acquires all characters that make the building fabric lessen the energy requirement of the building. Moreover, the seismic retrofitting envelope can be experimented with to achieve advanced innovative solutions, like developing hydroponic urban agriculture and food producing systems which can reach out to diminish the ever-growing carbon footprint of modern city settlements and reinstate the use of urban land for food production. The addition of a hydroponic food production system on seismic retrofitting envelopes makes the resolution more comprehensive and meaningful as it is economically viable to invest on a structure that has the ability to gather returns overtime. This solution not only targets the issue of seismic stability but also eliminates the burden on infrastructure due to constantly increasing population, food shortage, CO_2 emissions, deteriorating urban environment and quality of life. It brings about a ballance between economic and environmental sustainability.

Design Proposal: Geometric cells

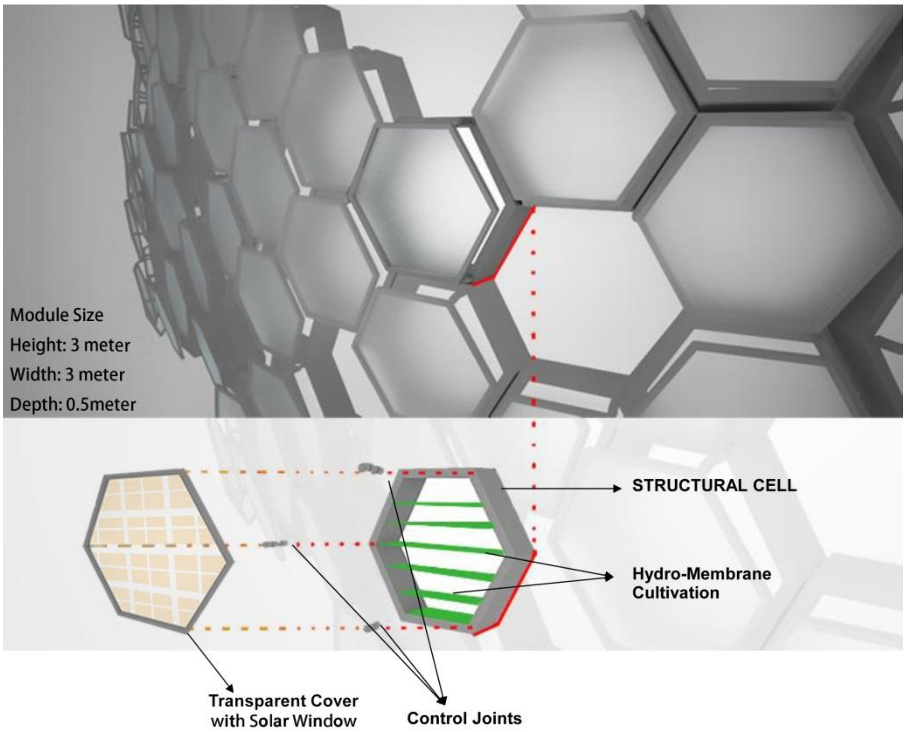
The selection of a seismic retrofitting design system must be decided after contemplation and analysis of structural soundness, stability, performance and cost. One such study has analysed a hexagonal grid exoskeleton to be rigid for the purpose of structural stability and cost effective at the same time. The study compared the hexagonal grid structure to regular triangles, squares and pentagonal grid structures to arrive at this result.

The retrospective seismic envelope structure that allows food cultivation, hence constitutes of numerous hexagonal cells. Each of the cells is a food production unit equipped with a Hydro-Membrane system as plant cultivating media. Every cell has a Transparent Cover that prevents growing plants from the impact of natural forces, such as storms and winds. Structural cell and Transparent Covers are connected by three Control Joints which achieve flexibility by adjusting both the size and direction of opening, and optimizing local ventilation.

Every hexagonal element works as an independent semi-open laboratory producing food. This not only means that there is no interruptions between cells, but also reflects on its feasibility. Structural frames separate cells by their varying cultivation purpose or species, which prevents unexpected disease to spread from plant to plant. The varying space requirements of different plants can be easily fulfilled by individual density setting, more importantly; the flexibility of plants' growth pattern and settlement dictates the best efficiency of space use. Scientific and reasonable use of spaces can always save resources. Vertical layout of cultivation system makes it possible that more food production can be achieved per unit of ground area.

Hydro-Membrane Cultivation Media

A new hydroponic system known as IMEC has been invented by Japanese scientist Dr. Yuichi Mori from Tokyo-based scientific firm Mebiol (PRLOG, 2011). The system uses 'Hydromembranes' as the primary medium to grow plants. 'Hydromembranes' are constituted by hydrogel-filled substances, which have high absorbing quality, and this material is generally used in diapers; further on, Hydrogel contains water and mineral solutions providing adequate nutrition for the proper growth of plants (Mebiol, 2013). This self-sufficient supplementary growth technique can be used on different surfaces, even concrete and ice, which is surprising. This is to say, the types of foundations that support this hydroponic system is not defined, and in turn, hydromembrane cultivation system will not affect foundations that it attaches on. Further, this technology makes it possible to grow food in extreme arid climates like the deserts where natural ground is not an appropriate plant growing media (Kraemer, S., 2012). Even though the sizes of the plants cultivated by IMEC is slightly smaller, their quality is significantly much higher than the traditional food produce, because the duration of plant growth is slow and elongated due to slow rate of nutrient absorption. The growing crop in turn synthesises higher levels of sugars and amino acids within, making IMEC tomatoes and cucumbers sweeter and more nutritious than the conventional produce (PRLOG, 2011).



Hydromembrane technique makes the advantages prominent in seismic retrofitting envelopes. They are extremely thin and light, IMEC technology minimizes the volume of soilless food cultivation equipment. The conventional hydroponics and aeroponics are usually functioning on a relatively big foundation which needs to provide space for plants' root system and nutrition flow that is delivered by a nutrition nozzle or contained by rooting mediums. It seems that this relatively large demand of space has become one of the higher reasons for drawbacks that hinder designers to propose large-scale vertical food production building fabrics. The large volume limits the crop yield within the designed height of grid- cell structure and increases the cost of per unit crop yield. Also, the weight of plant growing systems and equipment usually challenge the designed structure and increasing structural complications. However, the Hydro-Membrane can be easily attached on almost all kinds of modern construction materials, which in turn, do not influence the structural system and building fabric during or after the cultivation process. As a consequence, the light, thin and harmless characteristics of IMEC make the system qualify as flexible and feasible.

Resultant Effect of Design Implementation

Take the tomato producing process as an example, the producing area in each cell of this envelope will be six times more than traditional soil-based food cultivation systems. In addition, if certain plants do not need much vertical space, such as lettuce (leafy plants), the cultivation area is almost ten times more than that of soil-based farming. It is important to note that this significant improvement is just achieved by a single structural cell of the entire building exoskeleton fabric. In the context of urban scale implementation, the structure comprises of a multiple grid forming the protective envelope along the downtown high-rise buildings or skyscrapers, the food produce shall be multiplied with every successive floor. For example, if a 30-meter-long, 30-meter-wide and 100-meter-high building is protected by a seismic retrofitting envelope which is 0.5 meters thick and has cells that are 3-meter-high, it can provide approximately 17820m^2 ([30/3x4x100/3]x13.5m^2) of cultivatable area by increasing only 60m^2 (0.5m^2x30x4) to the existing footprint area around the building. Simply put, higher the building is, more the food production will be.
The orientations and sizes of individual Transparent Covers' opening can be easily adjusted by regulating the positional relationships between Transparent Covers and Control Joints. This will not only protect both the cultivating plants in between external and internal envelopes and the buildings from the unexpected damage caused by extreme weather conditions, but also create a possibility to optimize buildings' ventilation system. Gales and rainstorms may negatively influence the growth of plants or damage the surfaces of buildings. In general, growing plants in envelopes functioning like green facades are capable of adjusting the building's temperature as per prevailing climate. This system has all the advantages of an integrated double envelope system, as it is one of the types, i.e. the energy requirements of the building are sufficiently reduced due to the climate responsive- sustainable design of the building fabric.
To enhance the efficiency of the building envelope, the exterior most surface of Transparent Covers can be equipped with Solar Windows---which are a new innovation of electricity-generating solar coating technology. This transparent material is made from natural polymers and constituted by ultra-small solar cells, which achieves its abilities to be dissolvable in liquid and sprayed on to glass, plastic and even paper (New Energy Technologies, 2014). Compared with traditional silicon wafers, it is more tensile and stronger and also much cheaper; compared with other solar coating technologies, it does not demand high-temperature or high-vacuum techniques during the process of production (New Energy Technologies, 2014). Additionally, it is highlighted by New Energy Technologies (2014) that ultra-small solar cells can generate electricity energy under not only natural lighting condition, but also artificial lighting condition, and its thickness is one tenth of the contemporary thin-film technologies, but the electricity generation efficiency under artificial lighting conditions is surprisingly ten times more than them. It seems that this extremely thin material makes its transparency considerably high. It is significantly notable that this system can generate electricity efficiently without sacrificing the volume of light on the other side of the material. As a consequence, the growth of plants in Structural Cells will be contained. Besides, the controllable angles of Transparent Covers will maximize the capacity and potential of Solar Window's energy generation by changing its orientation with the changing sun-path in the day. This provides for the ultimate energy efficient solution of implementing this design. The strategy targets five important sustainable issues:

- Makes the building structurally sound from prospective earthquake threats
- Increases healthy and fresh food produce for an urban setting
- Reduces overall carbon footprint of the urban settlement
- It aims to reduce carbon emissions due to a long chain of processing and transportation of food resources from rural to urban areas.

- Like a typical double skin envelope, manages to significantly reduce energy requirements of the building
- Lastly, implementing energy generating strategies on the outermost skin of the system would make the building design Energy-plus

CONCLUSION

The paper has been able to propose strategies that:

- reduce the net energy requirement of a high-rise building.
- help contain the carbon footprint of the ever- evolving dynamic downtown.
- provide agricultural aspects with-in the urban set up, decreasing carbon emissions that result from far-off rural agricultural set- ups.
- curb heat island phenomenon in developed urban zones with large coal tarred spaces and absorbing building surfaces, by designing green or energy generating surfaces and galleries around town.
- help the building attain structural efficiency in a high seismic zone
- effectively allow the building fabric to generate energy to suit its own requirement and at a scale that it is possible to feed back the city lines.

It is obvious from the calculative analysis of the three proposed strategies, that implementing them on the city district scale in Auckland would lead to an ENERGY-PLUS DOWNTOWN.

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