Living Green Shell: Urban Micro-Vertical Farm

Jeanne Lee *jeanne@mail.mcu.edu.tw*
Department of Architecture
Ming Chuan University
Taipei, 111, Taiwan (R.O.C)

I-Ting Chuang *iting_chuang@post.harvard.edu*
LeChA Architects
Taipei, 106, Taiwan (R.O.C)

Abstract

In order to reduce the urban heat island effect and increase cooling insulation, certain innovative cities rely on the benefits of vertical greening system. However, finding the space in a highly-developed city such as Hong Kong and Taiwan is a significant challenge. Facing the same challenge, cities like New York, Tokyo and Singapore, develop vertical greening system such as green walls, green roof, or urban agriculture to maximize the greening capacity. However, the green-roof development in Taiwan faces the challenge of the unique culture of architectural additions, known as sheet metal housing. The roof-top sheet metal housing is commonly used in most of the Taiwanese communities and occupies the roof space. Moreover, this sheet metal not only limits the scale of greening development, it also increases the indoor temperature and energy consumption with its heat-transfer nature. According to the research, the Living Green Shell functions as shelter, cooling insulation, air purifier and helps improve cooling efficiency in conjunction with the concept of vertical farm. Through the BIM simulation evaluations, the research focuses on how the cooling insulation of the Living Green Shell (LGS) over the sheet metal buildings could give a better energy-saving efficiency. The micro-vertical farm system is evolving from LGS 1.0 to the final version, LGS 3.0 to improve related functions. The LGS also provides edible vegetables and produces solar energy via the mini-solar bites. With the sheet metal housing's easily fabricated nature, the housing could be integrated with the LGS devices and led to a broad implementation in Taiwan with proper promoting.

Keywords: Green-roof, Sheet Mental Housing, Micro-vertical Farm, Energy-saving Efficiency, BIM.

1. INTRODUCTION

Over the past two decades, the sustainability of vertical greening system has evolved into living green architecture components which meet the needs of energy saving. Cities like New York, Hong Kong, and Singapore, with the rapid growth of the highest building density in the world, had relied on green walls, green roof, or urban agriculture, to maximize the greening capacity and to mitigate the Urban Heat Island Effect (UHIE). One of the major challenges of the green roof development in Asia is the broadly-spread sheet metal buildings on the rooftop. The unique architectural additions often occupy the roof space and limit the scale of greening development. The situation takes place in Taiwan and most of the Asian cities. Though the heat-transfer nature of the metal sheet housing increases the indoor temperature and energy consumption, the consumers enjoy the advantages of low cost and speedy assembling. The advantages, somehow, had hindered the development of a greening urban environment. Through the analysis of BIM simulation tests, the results show the LGS functions not only as a shelter to the sheet metal building, but also a cooling insulation and air purifier. Therefore, the study focuses on evaluating the energy-saving efficiency via comparing the performances of Living Green Shell (LGS) to the sheet metal building's façade. Moreover, the additional function of micro-vertical farm can be promoted through the light-weight LGS where edible vegetable planting is made possible. Based on the easily-fabricated feature of LGS system and the large quantity of metal sheet roof-top housing, the establishment of the system would efficiently reduce the urban heat effect and improve the aesthetics of the cityscape from the metal-sheet building phenomenon. Therefore, the LGS devices also help promote vertical farming in which new urban life style could be refresh, re-established and redefined.

FIGURE 1: Mental-sheet Housing.

2. VERTICAL GREEN

Originally, the initiatives of urban greening are developed to level up the eco-friendliness in an urban setting and to scale down the negativity through the urban development [1] [2] [3].

The real estates in the high-density urban areas are valued as gold and measured by inches. To intervene the issue of limited land resource, building envelopes, the vertical greening approach, is considered as one of the accessible and feasible solutions for “creating” greening space. It can be constructed over the exiting roof or walls [4].

Vertical Greening System (VGS) is a general term of multiple and vertical greening modules, including green-wall technologies, vertical gardens, and bio walls. The VGS can also be divided into two categories, Green Façade & Living Wall. The modules are versatile based on the vegetation and architecture shapes which vary from basic framework to high-tech vertical structure.

VGS, traditionally, serves as a passive bio-filter. The Green Façade, vegetation can be found on earth or in the pots, be attached to the walls or placed on the rooftop. Generally, one of the most common practices is to grow single species of plants with comparatively low density and easy nursery. While the Living Wall system, with the latest technologies, has advanced into an active and more complex eco-system, equipped with water-proof, irrigation, monitor, and lighting devices. The plants and vessels are built in for a more pleasant environment where the airflow runs through, heat is reduced, and humidity is increased. The long-term outcome is an effective reduction of the energy consumption and operating cost [5] [6] [7].

In addition to the micro-climate adjustment, some scholars recently discover that covering building façades and rooftop with the greenery is one of the most effective strategies for reducing heat island effect in a highly-dense urban environment [2] [5] [9]. Researches show that through the shading and evapotranspiration cooling effects, proper vegetation may directly and significantly reduce outdoor heat and UHIE [10]. According to the statistics of the Environmental Department of the German Stuttgart, the greening shade significantly reduces the highest temperature on the building facade and generates daily temperature gap up to 50%. The solar heat can be evaporated into latent heat and keep the temperature from escalating. Meanwhile, the statistics also demonstrate that concrete buildings covered by the greening shade gain less heat compared to the bare ones. The finding enhances the positive impact of the Vertical Green on countering the UHI [11].

One more advantage of the Vertical Green is to improve aesthetic and advance the strategies of energy saving campaign which effectively narrow the disconnection between the urban areas and natural sites [12]. On the other hand, some research suggests that green vegetation nurtures mental health and generates positive outcomes [13]. Lastly, the research of Odum compiles the public and private benefits and value of green walls (Table 1). The conclusions re-affirm a broad scope of benefits spun from the vertical green that is aesthetical, societal, economical, and environmental [14].

Public Benefit	Private Benefit
◦ Reduce Urban Heat Island Effect	◦ Improved Energy Efficiency
◦ Improved Exterior Air Quality	◦ Building Structure Protection
◦ Aesthetic Improvement	◦ Improved Indoor Air Quality

TABLE 1: List of Public and Private Benefits.

As the global trend leads to the concept of establishing green cities, numbers of scholars focus on the design of vertical farms, a variant environmental alternative replacing horticultural plants with edible vegetables. The greening alternatives can also well-function for food supply, recreation facilities, recycling rain and kitchen waste plus the opportunities of life education [16]. Cases of success have been demonstrated in metropolitan cities like New York, Singapore, and Hong Kong [17].

3. PROBLEM AND METHODOLOGY

The sheet metal housing is one of the most popular and easily-built shelter, expanding in both urban and rural areas. It reflects the demands of the residents under the typical weather pattern.

The slanting roof over the existing buildings redefines the space of the architecture. The materials are originally used for patching repair or creating extensive space and, later, advanced into a portion of the internal space [18]. Roof-top space (attic) has been habitually privatized and internalized which greatly eliminates the possibility of green- roof approach. According to the United Nations’ indicator, the minimum green space for an individual person is averaged 20 m². The average rate of Taipei citizens reaches only 25% of the UN indicator, an obvious lack of green space. If the sheet metal housing is effectively turned into a green instrument, the average number of green land for individual citizens can definitely be elevated to ease the environmental concerns and improve the urban aesthetics. The objectives of the study are listed as below.

1. Expanding the roof-top green space to benefit the residents.
2. Developing green wall system with a rapid execution plan by applying eco-friendly materials and offering training of the execution manners.
3. Establishing new complex devices of roof farming agriculture that adapt Taiwanese contexts.

Most of the Taiwanese adjunct construction materials are considered unendurable and cheap. The wavy metal sheet is one of the most popular items which serves the interests of short-term construction, bearable safety, and low cost. Physically, the materials lack of insulation from cold, heat and noises, while the installment of green wall may effectively improve the micro-climate and beautify the building appearances. The sheet metal housing is often erected illegally due to the unmet demands of more space and limited construction resources (though the residences understand the risk of the structure being demolished). The statistic provided by the County and City Government has shown that currently there are 673118 of this illegal sheet metal housing structures country wide (Table 2). The strength of the GLS fulfills the unmet needs. For the feasibility of the green device installment, the features of the sheet metal housing, a reasonable construction cost, and a well-streamlined execution plan are considered and integrated as below.

1. The device installment should be based on accessible materials and popular (or easily adaptable) execution

2. Modularization and small units are translated into the design so that the flexibility of the installment is maximized and fits all circumstances (locations and space).
3. Cost-effectiveness in energy saving, carbon reducing, and self-sustaining installment for the sheet metal housing

May-17			
Cases			
區　域　別 Locality		Total	
		Up to Date Yet to Demolished	Up to date Demolished
總　　計	**Total**	673,118	2,843
新北市	**New Taipei City**	205,926	1,797
臺北市	**Taipei City**	85,873	374
桃園市	**Taoyuan City**	58,416	41
臺中市	**Taichung City**	75,091	197
臺南市	**Tainan City**	28,047	78
高雄市	**Kaohsiung City**	122,658	222
臺灣省	**Taiwan Province**	93,755	134
福建省	**Fuchien Province**	3,352	-
金門縣	Kinmen County	2,770	-
連江縣	Lienchiang County	582	-
By County and City Government			

TABLE 2: Illegal Construction Demolition Cases.

The methodology of the study is based on case study and BIM digital environment simulation technology where the statistics of the features and modules of roof farm are analyzed to understand the adjustment of micro-climate and the device effectiveness. Simultaneously, ten cases are selected, observed and analyzed by referring to the variances of time, country, climate patterns and scales. The process of reasoning is expected to design the prototypes and modules of the devices which adapt to Taiwanese sheet metal housing. Via the contents of micro-vertical farm devices, BIM is drafted for simulating and analyzing the accuracy of the variances.

4. EXAMINATION OF THE CASES

According to the statistics of Architecture and Building Research Institute, Ministry of the Interior, residential buildings with a significant level of greening save 40% energy consumption in the summer. More international and domestic success stands out, such as the vertical green wall at the Expo 2010 Shanghai, China and Park Lane by CMP, Taichung, Taiwan. The statistics of both cases testify the positive impacts of green wall in temperature insulation and energy saving. Green wall is also known as the vegetation growing over the vertical surface of a building or of a certain external framework [19].

The green wall is generally categorized in three types:

1. Green wall with vegetation,
2. Green wall with mini pot plants (on the framework)
3. Green wall with pocket plants.

On the other hand, the constructional pattern of the green wall can be classified in two modules, 2D and 3D. The 2D green wall structure is organized by key elements such as cable, rods grids or nets, known as tension structure. Unless an independent supporting framework is constructed, the green wall takes advantage of the existing walls and is often erected close to the buildings. The critical point of the construction process is to evaluate the symbiosis between the vegetation ecology and buildings in terms of wall materials, strength and load-bearing capacity. The 3D green wall is a thick framework which is either braided (or welded) with gauge steel wire or structured panel with integral truss. With the solid skeleton, the 3D module allows the flexibility of a freestanding structure or span over openings. One of the greatest advantages of the 3D system is the thickness of the structure extending space for the vegetation to thrive and following tasks of maintenances. The key is to affirm the ecological integration of the vegetation and green wall system. Issues of maintenances emerge without the consideration of the symbiosis. [9] [20].

Ten cases are selected for observation and analysis in terms of time, country, climate pattern, and scales. The related comparison and induction of the variances are conducted. The analysis of the correlation between regional and material factors is conducted simultaneously (Table 3).

Case #	Project	**Architect(s)**	**Location**	**Year**
1	MFO-PARK	Raderschall/ Burckhardt + Partner AG Architekten	Switzerland	2002
2	Ex Ducati	Mario Cucinella Architects	Italy	2006
3	Firma Casa	SuperLimão Studio+Campana Brothers	Brazil	2010
4	Perth's Greenhouse	Fitt De Felice Architects	Australia	2010
5	Living Pavilion	Ann Ha and Behrang Behin	USA	2010
6	Vertical Garden	Urbanarbolismo	Spain	2011
7	San Telmo Museum	Nieto Sobejano Arquitectos	Spain	2012
8	Green Cast	Kengo Kuma	Japan	2012
9	3D printed planter bricks	Rael San Fratello Architects	USA	2013
10	Babylon Hotel	Vo trong nghia	Vietnam	2015

TABLE 3: Case Lists.

Case 1 MFO-Park Raderschall (2002)

FIGURE 2: MFO-Park Raderschall.

The award winning MFO-Park is a double-layer, steel-frame construction where the wire mess is covered with the climbing plant. The double-wall area with a sun deck on the roof top contains staircases and is floored with recycled glass. Located in the industrial area of Zurich, Swiss, the public park stands as the largest pergola in the world and the steel structure is specifically designed for overgrown plants. The spacious hall is transformed into an urban park with lush climbing plant and serves as a multi-purpose venue for events like film screenings, concerts or performing arts.

Case 2 Ex Ducati (2006)

FIGURE 3: Ex Ducati.

The project is a commercial unit on a redeveloping site. The upper floors accommodate office units with an L shape layout; while the building façade presents an urban frontage with some green skin and arches at 90° with the street-side clad. In order to create the appearance of vertical climbing gardens, the supporting structure is mounted with the 60 x 60 cm2 matrix stainless steel grid. The green envelopes are covered with the green skin system which is secured in the existing structure of the reinforced concrete.

Case 3 Firma Casa -Geometric Planter Façade (2010)

FIGURE 4: Firma Casa -Geometric Planter Façade.

The façade of the 500 square meters, two-story Firma Casa Showroom is a wire grid system and mounted with thousands of hanging aluminum vases individually filled with the snake plants. Concerning the neighborhood is threatened by heavy rainfall and flood, the designer features the framework by hanging vases with some in-built draining system which channels water flow from one vase to another and eventually to the ground. The snake plants are chosen due to its symbol of ritual power in some African-Brazilian religions.

Case 4 Perth's Greenhouse (2010)

FIGURE 5: Perth's Greenhouse.

Inspired by a concept of a 'pop-up' restaurant form and zero-carbon footprint, the greenhouse stands in a style of simplicity with a steel-framed, straw-insulated structure on the plywood-clad. The building has a self-renewing yet organic exterior.

Case 5 Living Pavilion (2010)

FIGURE 6: Living Pavilion.

The designers, Ann Ha and Behrang Behin, provide a low-tech and low-impact plus inverted green roof by using recycled milk crates as a framework. This curving framework is not only a green living wall with a plant-growing surface, but an evapotranspiration device for moderating interior temperature. As the plants proliferate in the common object like milk crates, the installation reduces the construction cost and heat-island effect and brings back the vitality of the urban environment.

Cast 6 Vertical Garden (2011)

FIGURE 7: Vertical Garden.

The vertical garden of the four panel eco-bin green wall consists of planted ceramic terracotta containers. Located in central courtyard of the hotel, the planted containers of the vertical garden are interconnected with growing vegetation, which also functions as a sound-absorbed barrier. For a better water absorption, the ceramic vessels provide a new system of green wall garden with a combination of dripping and hand irrigation. The selected vegetation has to adapt to any kind of weather conditions which makes possible an automatic gardening system.

Cast 7 San Telmo Museum (2012)

FIGURE 8: San Telmo Museum.

The new extension of the historical San Telmo Museum has a perforated aluminum façade with a semi-plant wall system. This wall system is mounted on the main structure's steel frame which is made of two-side panels with penetrated holes all over the panels. The multiple functions of the angled holes not only allow the plants to grow out and through, but to expand a larger scope of the appearance over the ancient stone of the existing building.

Case 8 Green Cast (2012)

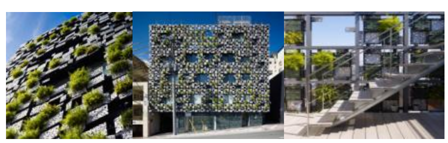

FIGURE 9: Green Cast.

With the multi-facet effects, this living façade is made of the slightly slanted aluminum panels and die-cast from decayed styrene foam, acting as vertical planters. The plants sprout from the tiny holes of the aluminum façade, which presents a bumpy texture of the patchwork. The downpipes are installed behind in order to reserve rain water for keeping the vegetation alive.

Case 9 3D printed planter bricks (2013)

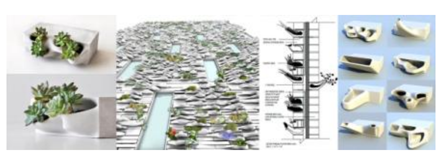

FIGURE 10: 3D Printed Planter Bricks.

Through the rapid 3D prototyping technology, Real San Fratello Architects "printed" emerging objects of the bricks which are installed into a building façade. The bricks are assembled and composed in a load bearing cavity wall, which varied in sizes and shapes (be it angular or curvaceous). With certain simple construction, the bricks are either combined with the steel frame as a traditional masonry curtain wall or installed into the existing walls. The planter bricks are turned into an instrument for evaperation, sound filtering, and micro-climate temperature mediating, which generates eco-friendly benefits to the urban environment.

Case 10 Babylon Hotel (2015)

FIGURE 11: Babylon Hotel.

This leafy waterfall-like green façade renovation had transformed an old building into a hanging garden. The flourishing veil of plants and vines climb over the vertical concrete louvres of the multistory hotel. Vo Trong Nghia Architects erected a screen of plant-covered façade as a shelter from the direct sunlight, which simultaneously allows the breezes to flow through and cool off the temperature on the building surface.

Project Name	Scale			Material				
	Building Scale	Façade Scale	Wall Scale	Wood/ Bamboo	Concrete	Metal	Plastic	Clay
MFO-PARK	X					X		
Ex Ducati		X				X		
Firma Casa		X				X		
Perth's Greenhouse		X						X
Living Pavilion			X	X			X	
Vertical Garden		X						X
San Telmo Museum		X			X			
Green Cast	X					X		
3D printed planter bricks			X					X
Babylon Hotel		X				X		

TABLE 4: Case List.

5. DESIGN PROCESS

FIGURE 2: Factors For The Analysis Design Process.

Through the case study above, five critical factors are identified and developed into a design process available for the final experiments. The five key factors are as below.

- Materials
- Details
- Assembly
- Form
- Interactions

In terms of the materials, it is crucial to select the building materials that meet the needs of heat insulation and speedy/independent assembly process. The study of Case 6 and 13 demonstrate high and positive green efficiency of the façade. However, the expensive cost of construction and confinement from self-assembling can delay the construction mechanism. While in Case 1, 4 and 7, the cost is scaled down due to the ceramic materials. However, the output of heat-countering efficiency turns to be low and less desirable. As for Case 2, the lighting functions well at night which promotes the concept of self-sustainability and generates one of the most desirable eco-efficiency structures. That leads to one of the features of the study, that is, a self-renewable structure where solar bits are equipped for night-time lighting.

For the choice of vegetation, the study focuses on three – the climbing vine and two types of edible vegetable. The former is selected to grow and climb over the structure and/or framework; the latter (two) are chosen for speedy and adaptable growth in the urban planters.

One of the findings of the case study is the need of forming a preliminary structure of the design process. That is to apply the five factors to generalize the design process which will be integrated with the LGS for an urban micro-vertical farm. One other crucial finding is that the quality materials have to be accessible/ recyclable, allow easy and rapid assemble, and perform high energy-saving efficiency. That turns out to be one of the most decisive factors in the process. In the aspect of assembling, the core strategy is to pursue light-weight devices with the energy-saving advantage plus rapid-erecting convenience which accelerates the promotion of LGS. The research direction is set to present the evolution of the design process, concluded from the factors' operation, serves as an instrument to evaluate and analyze the selected 10 cases.

6. EXPERIMENTS AND ANALYSIS

The smooth and wavy surface of the sheet metal housing does not allow planting and growing of the liana vegetation. The only feasible green wall is the type with mini pot plants on the framework. Plants growing in the individual units of a small vessel are displayed in a diverse fashion on the wall frame. The elements of the green wall are a structured framework, planting vessels, and proper plants. The prototype, therefore, is established and integrated with eco-friendly and sustainable materials for producing the planting vessels, e.g. bamboo, milk jugs (replacing the light-weight metal structure) in addition to the solar panel and LED lighting. The components can be attached to or structured with the surface of the exiting sheet metal housing. The combination of the roof-scape creates a new pattern of self-sustainable and micro- urban landscape in the air.

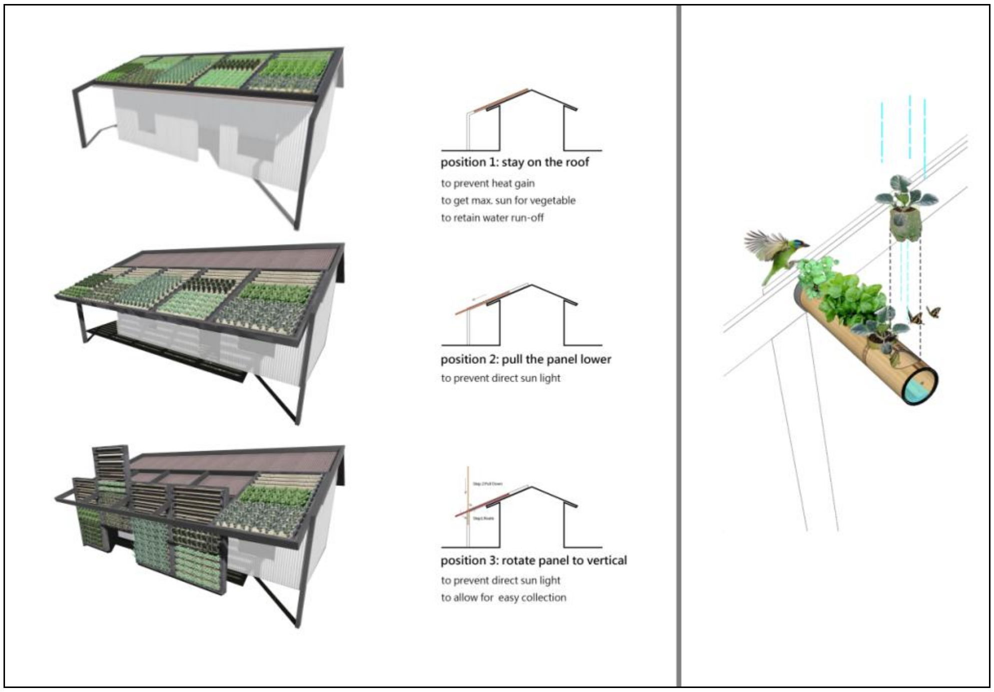

FIGURE 12: Second Layer of Land (LGS 1.0).

There are two simulation prototypes of the research design and both are award-winning projects; one, named The Second Layer of Land Project, is granted with 2016 Professional Concept of "if Design Award" (Figure.12).and the other, entitled Urban Green Light Project, with A'Design Award 2017 (Figure.4). The projects are inspired by the unique Taiwanese urban phenomenon of sheet metal housing (popular island-wide) where the roof-extension space often functions as a living space without livable housing facilities.

6.1 The Second-layer Land (LGS 1.0)

It is a number of portable frameworks structured into a framework to cope with the slanting roof of the sheet metal housing. The device is adjustable in altitude and serves as a cooling system, well-shading the roof-top yet securing a large intake of sunlight. For the environmental and cost concerns, bamboo, one of the most common vegetation in Taiwan, is selected to form the skeletons replacing light iron frame as an eco-friendlier material. In the project, recyclable porter bottles are transformed into planting vessels due to their wide accessibility for convenient replacement (Figure 12). The module forms an extra skin layer over the building, also known as a building envelope, which shades the architecture from excessive heat. On the other hand, the concept of urban vertical farm can be integrated with LGS 1.0 to grow edible vegetables where both alternative crops supply and the leisure gardening are made possible.

The LGS 1.0 are versatile in three modules (Figure 12):

1. Stationary on the Rooftop: All panels are lifted to the roof-top for heat insulation and generous sunshine to grow plants.
2. With Lower Altitude: Panels are lowered down to create deep shade over the building.
3. Rotate to Vertical: Panels are moved and positioned vertically against the ground for window shade or harvesting the crops.

Units of the system are supported by bamboo and light iron frame. The structure is usually layed out on the roof top which is organized and shaped according to the appearance and size of the sheet metal roof.

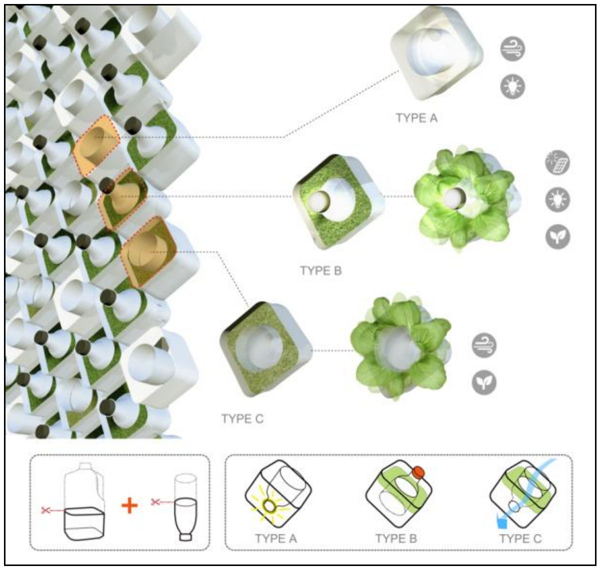

FIGURE 13: The Urban Green Light (LGS 2.0)

6.2 The Urban Green Light (LGS 2.0)

It differs from LGS 1.0 by integrating the physics theory of wind tunnel where the ventilation is accelerating to decrease the room temperature of the metal-sheet housing. Through which, the reduction of energy consumption is made possible. LGS 2.0 shares the cleverness of pre-fabricated installation of the off-shelf materials where two types of recycled containers with two different sizes are connected like Lego blocks to form the system (Figure 13).

The design is a modularized and flexible eco-building façade system for a region in the sub-tropical climate. The module is made of recycled plastic milk jugs and bottles with three different compositions incorporating small solar panels, planter and LED lights as needed. The module could act as an extra layer of the building skin to provide shading and prevent heat gain on building envelope. It also actualizes a breathable skin concept that utilizes the wind-funnel to increase ventilation and to optimize the micro-climate of the built environment.

The module units are staggered together and supported by light-weight metal frames to be secured on any building façade and shapes as suited. The materials are designed to be eco-friendly by using recycled plastic bottles and economically sound as incentives for a wider installation (Figure 13).

The LGS 2.0 system has three modules:

1. Module A is the combination of two elements - a small plastic bottle (as “wind funnel”) and a big plastic milk jug (lower half) installed with solar bites around the edge.
2. Module B is the combination of two elements - one small plastic bottle capped with a big solar bite, centered on top of a big plastic milk jug (lower half as a recycled bottle planter)
3. Module C is the combination of two elements - a small plastic bottle (as “wind funnel”) and big recycled plastic milk jug (lower half as the bottle planter)

Through the BIM simulation, the heat gain of the typical sheet metal housing (without Green Wall installation) rises higher than the ones with LGS devices demonstrated in Project I and II. (Figure 14) The results testify the efficiency of LGS in shading buildings from heat gain. Meanwhile, the modules of the SLL project even present the statistics vary in positions where the readings of the vertical device (position 3) significantly levels up the greening effect better than the other positions (#1 & 2). In the UGL project.02, with vertical green devices in the walls and wind tunnels, an advanced integration of the strength of SLL and UGL, the energy-saving effects are promoted to a new level high (Figure 16) and, therefore, produce an eco-friendly and versatile LGS. One of the key conclusions from the BIM experiments suggests that the density of the vegetation directly affects the greening efficiency (Figure 17). The simulation of this study is based on the impact of the presence of devices on energy savings. Due to the fact that there is no standard size for metal-sheet houses in Taiwan and the device is completely attached to the existing building. Therefore, the performance data for each device will vary from case to case. The difference on energy saving efficiency can be clearly seen on the simulation diagram.

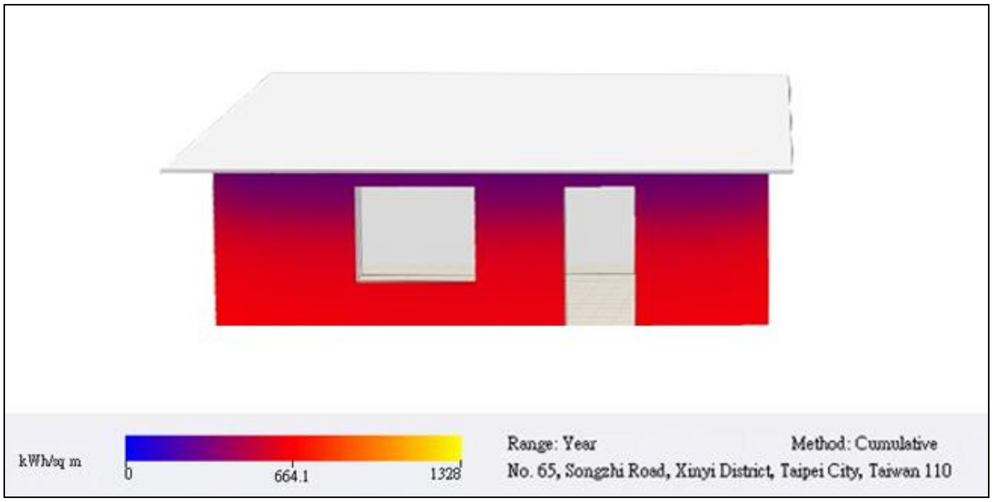

FIGURE 14: BIM Thermal Analysis Without LGS.

FIGURE 15: BIM Thermal Analysis for LGS 1.0.

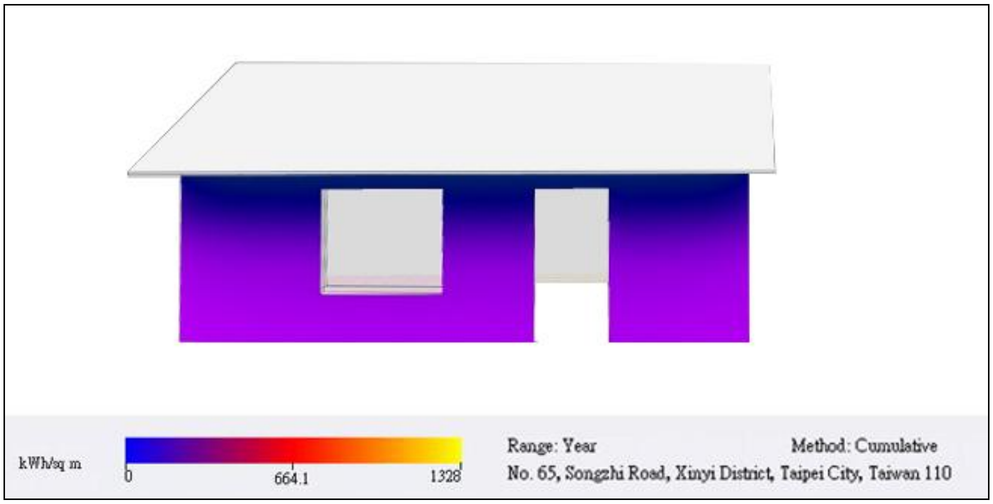

FIGURE 16: BIM Thermal Analysis for LGS 2.0.

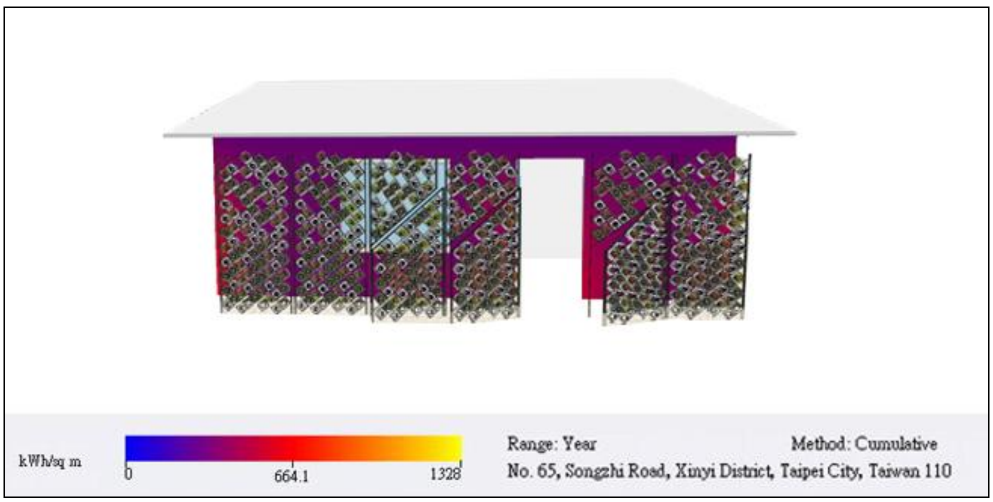

FIGURE 17: BIM Thermal Analysis for LGS 3.0.

At the final stage of the study, the researchers integrate the key concept of both projects by simplifying the structured framework of project I to reduce cost and increase versatility of the installation. However, the materials and complete modules of project II are completely secured for flexible combinations of the units which allow a greater feasibility for shapes and sizes of the space. Lastly, taking advantages of the 3D green façade system, that is sustaining a freestanding structure and spreading over an opening, the panels in the framework are equipped with the rotation mechanism. Through which, the panels rotate depending on timeline and weather conditions for a greater shading efficiency and, therefore, hang a “green” veil over the urban concrete jungle (Figure 18).

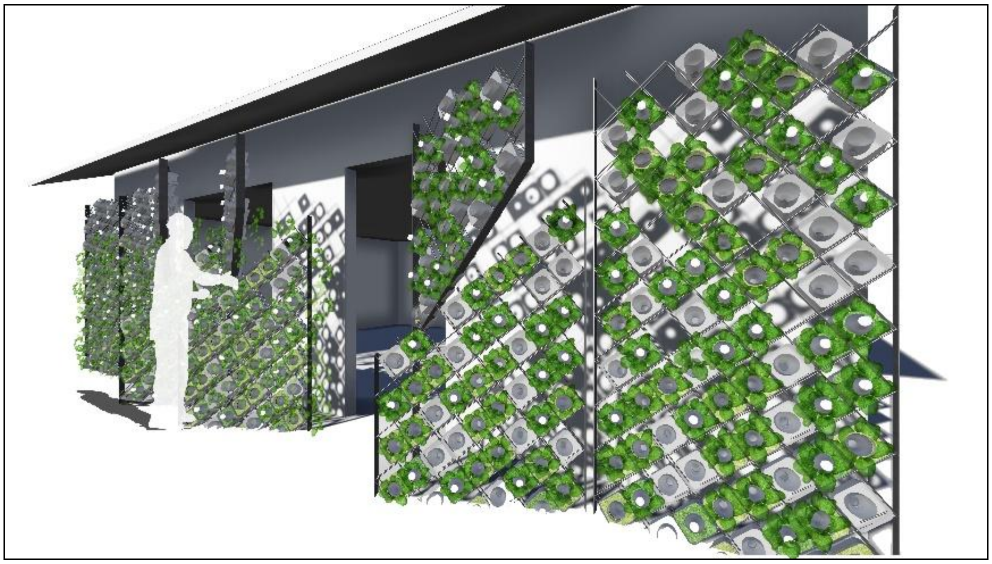

FIGURE 18: LGS 3.0.

7. CONCLUSION

Originally, the research aims for the cityscape improvement and advancement of the urban architecture via the promotion and installment of the Living Green Shell (LGS). It is expected that the façade of old buildings and metal sheet housing to be renew and redefined not just around the surface but on greening impacts with an affordable cost plus the solutions for energy saving countering Urban Heat Island Effect. In Europe, many old buildings experience an architectural rebirth through some green façade installations. The old/torn buildings and sheet metal housing in Taiwan could enjoy the similar opportunities where more than two birds can be killed in one stone. That is via implementing the LGS installment to easy the concerns of energy shortage, architectural waste, decaying old buildings, and poor cityscape torn by the metal sheet housing (Figure 19).

For future research purposes, the designed unit material selections can be considered with variable options to strengthen its heat-absorbing properties. Studies has shown that by adding the heat insulation materials that generally has heat-absorbing properties, heat will still penetrate into the metal-sheet house after enough accumulation; but "aluminum heat insulation blanket" uses a reflection principle that could reflect the majority of radiant heat. Therefore, experimenting with different materiality for the design installment could possibly strength it’s energy saving efficiency for the next step.

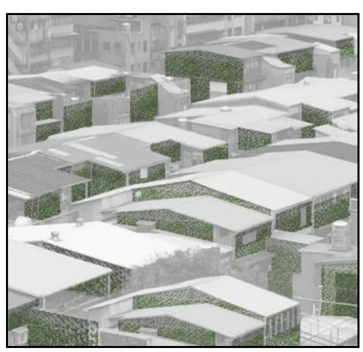

FIGURE 19: LGS Skyscape.

8. REFERENCES

[1] B. Bass and B. Baskaran. "Evaluating Rooftop and Vertical Gardens as an Adaptation Strategy for Urban Areas. "Institute for Research and Construction NRCC-46737, Project number A020" (2001).

[2] F. Gomez, E. Gaja, and A. Reig. "Vegetation and climatic changes in a city", Ecological Engineering 10 (1998) 355–360.

[3] L.M. Westphal. "Urban Greening and Social Benefits: A Study of Empowerment Outcomes," Journal of. Arboriculture 29: 3 (2003) 137–147.

[4] B.A. Currie and B. Bassn. "Estimates of Air Pollution with Green Plants and Green Roofs Using the UFORE Model" Proc. of 3rd North American Green Roof Conference Greening Rooftops for Sustainable Communities, Washington, 4–6 May. 495–511, (2005).

[5] L. Urrestarazu, R. Cañero, A. Salas and G. Egea. "Vertical Greening Systems and Sustainable Cities". Journal of Urban Technology, Vol. 22, Iss. 4, (2015).

[6] E.A. Eumorfopoulou and K.J. Kontoleon, "Experimental Approach to the Contribution of Plantcovered Walls to the Thermal Behaviour of Building Envelopes," Building and Environment 44: 5 (2009) 1024–1038.

[7] M. Manso and J. Castro Gomes, "GreenWall Systems: A Review of their Characteristics," Renewable and Sustainable Energy Reviews 41 (2015) 863–871.

[8] M. Ottele´, K. Perini, A.L.A. Fraaij, E.M. Haas, and R. Raiteri, "Comparative Life Cycle Analysis for Green Facades and Living Wall Systems," Energy and Buildings 43: 12 (2011) 3419–3429.

[9] Greenscreen, "Advanced Green Facade Design White Paper". Los Angeles, California, USA. p.5-6.

[10] McPherson EG. Preserving and restoring urban biodiversity: cooling urban heat islands with sustainable landscapes. In: Platt RH, Rowntree RA, Muick PC, editors. The ecological city. Amherst, US: University of Massachusetts Press; (1994). p. 151 72.

[11] Climate booklet for urban development. Ministry of Economy Baden-Wurttemberg in Cooperation with Environmental Protection Department of Stuttgart; (2008).

[12] Van Bohemen HD, Fraaij ALA, Ottele M. Ecological engineering, green roofs and the greening of vertical walls of buildings in urban areas. Ecocity World Summit, San Francisco, California, USA; 23 April (2008).

[13] Bellows, Anne C. et al. (2003). Health Benefits of Urban Agriculture. Paper made available by the members of the Community Food Security Coalition's North American Initiative on Urban Agriculture.

[14] Odum, H.T., 1995. Scales of ecological engineering. Ecol. Eng. 6 (1996), 7 19. Pekkanen J, Timonen KL, Tiittanen P, Vallius M, Lanki T, Sinkko H., (2000). Exposure and Risk Assessment for Fine and Ultrafine Particles in Ambient Air. National Public Health Institute.

[15] D. Despommier, "The Rise of Vertical Farms", Scientific American 301: 5 (2009) 80–87.

[16] M. Pryor. The Edible Roof: A Guide to Productive Rooftop Gardening. Hong Kong, MCCM Creations, (2016).

[17] R.Welte, "Vertical Farming Comes to Chicago. At the Plant, John Edel is Building the World's First Vertical Farm," Time Out Chicago (2011).

[18] F. Hung, A study on the Illegal Light Guage Steel Roof Construction in Tainan - in case of Tainan, National Cheng Kung University Department of Architecture, (2009).

[19] M.C. Wang, Facade Green Wall Green Vegetation Development of Shallow Medium, Carbon Reduction Green Construction Methods Green Roofs and Green Walls, Exchanges Discussion and Promotion Exhibition. Taipei City, Taiwan. pp.26- 43, (2009).

[20] F. Wilmers, Effects of vegetation on urban climate and buildings. Energy and Buildings, 15 (1990), pp. 507-514.