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Near Zero Energy Building In Tropical Climates - Case Alpes Office

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The objective of this bachelor's thesis was to illustrate that a near zero energy building (nZEB) could be constructed in hot and humid climate zones like Vietnam, with all standards and requirements fulfilled. The purpose was to achieve a sustainable, ecological, and environmentally friendly building in a dynamic city. A construction guideline could be created for this type of building based on both the results of this case study and the future performance of the building.

The thesis studied energy-saving building types, gathered knowledge from multiple sources, and collected experience from designed buildings. Furthermore, a design team was formed of the employees of two companies. The results reveal that it is indeed possible to construct nZEBs in hot and humid climate zones although there are still several difficulties and obstacles.

Keywords	near zero energy building, green building, green building certificate, sustainable, low energy house

Contents

List of Abbreviations

NZEB	Net Zero Energy Building
nZEB	Net Zero Energy Building
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method
USGBC	U.S. Green Building Council
SGBC	Singapore Green Building Council
VGBC	Vietnam Green Building Council
GDB	Green Design & Build
IBPSA	International Building Performance Simulation Association
LCA	Life Cycle Assessment
PHPP	Passive House Planning Package
OTTV	Overall Thermal Transfer Value
ASTM	American Society for Testing and Materials
Wp	Watt - peak
kWp	Kilowatt – peak
kWh	Kilowatt – hour
MWh	Megawatt – hour
EVN	Electricity of Vietnam
PV	Photovoltaic
AAC	Autoclaved Aerated Concrete
SA/V	Surface Area / Volume
VRV	Variable Refrigerant Volume
VRF	Variable Refrigerant Flow
COP	Coefficient of Performance
MPPT	Maximum Power Point Tracking

1 Introduction

Human activities are impacting the environment in negative ways, such as the climate change and global warming, which are alarmingly crucial issues while overpopulation still continues. As the speed of urbanization is increasing all over the world, constructed buildings account for 20 to 40% of energy consumption and more than 30% of the global greenhouse gas emissions. [1.] There is a need to construct buildings and houses with less environmental impacts that consume less energy, by turning to renewable energy sources. According to research results, renewable energy will be able to help the Vietnamese electricity industry to achieve better results than the current ones when it comes to energy cost, energy cleanliness, and energy demand. [2.] Similarly, it is important to recreate a sustainable connection between human beings and the environment. Therefore, a new project is carried out to achieve sustainability with a building that can satisfy the requirements and standards of a near zero energy building (nZEB).

Alpes GDB (Green Design & Build) is an architecture firm that aims to achieve the goal nZEB for their existing workplace, Alpes office. Alpes GDB also needs a green building certificate for their building. Therefore, GreenViet Company is asked to be the consultant of this nZEB project. GreenViet provides energy solutions and helps Alpes GDB to get a green building certificate. This certificate is a confirmation that a building meets all criteria of a green building which is sustainable and environmentally friendly. LOTUS, a green building rating and assessment tool developed by the Vietnam Green Building Council (VGBC) for the built environment within the Vietnam region, is chosen to assess Alpes building.

In this nZEB project, the role of Alpes GDB is the client, providing materials concerning architectural, structural designs, and construction of the Alpes building, which were complete in 2016. GreenViet is responsible for giving the energy optimization solutions and registering the Alpes Building for the LOTUS certification. The author was an intern at GreenViet and assigned to the project. The author’s tasks were to design a solar panels system for the Alpes building and fulfill LOTUS’s requirements of a green building. The working methods were both direct and online meetings and interviews. The building services systems and project tasks are described in the next chapters.

The design phase for a solar power system and consulting phase for a LOTUS certificate have been complete. The project is currently put on hold for more discussion between

Alpes GDB and GreenViet. The next two steps afterwards will be to install the solar panels on the roof of the Alpes building and register the Alpes building for LOTUS programme.

The outcome of this bachelor thesis is expected to be either a case study or a design guideline for other similar green building projects, namely, nZEB and low energy building projects in Vietnam. Therefore, the thesis mentions not only the energy solution given by GreenViet in 2018 but also the Alpes building's structural design that was completed in 2016.

2 Near Zero Energy Building

2.1 Definition

Today's construction industry faces the challenges such as climate change, global warming, health and other environmental issues with new building trends. A few of them are the net zero energy building, near zero energy building and low energy building. The main purpose of a net zero energy building is to balance the energy consumption and onsite renewable energy production (figure 1), making the building's energy expense zero. This type of building requires high standards of building envelope, compactness, solar shading, energy efficiency, indoor air quality, and so on. [4.] Low energy buildings consume less energy than conventional buildings, and use more renewable energy technologies. [5.]

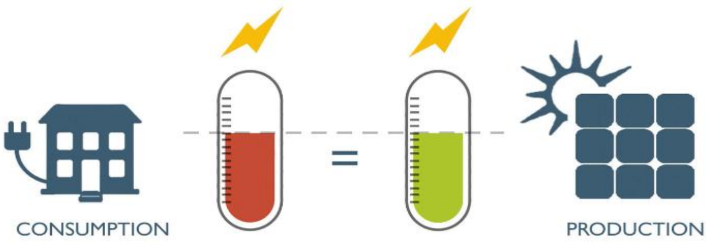

Figure 1. The basic principle of a Net Zero Energy House. [6.]

Near zero energy buildings are closer to net zero than low energy buildings. A near zero energy building reaches a near energy balance in areas including heating, cooling, ventilation, lighting, and appliances, meaning that the building's total energy consumption is somewhat higher than the amount of on-site renewable energy production. Although the building uses energy from the grid which produces greenhouse gases, it also generates renewable energy onsite, thus reducing the production of greenhouse gases. [4.]

In general, nZEBs in Vietnam is still a distant goal. Due to a lack of knowledge, experience, environmental awareness and education, only few people pay attention to energy-saving buildings. A number of organizations, associations, and clubs have been established aiming to create and bring new opportunities to the built community. This action plays a crucial role in raising environmental awareness and promoting activities such as discussing, sharing, and exchanging knowledge and experience. At the beginning of 2018, IBPSA – Vietnam (International Building Performance Simulation Association) was established for the same purpose. This association sets building performance simulation as the main goal since building simulation is still a new design trend in Vietnam. [7.]

Because of the current excessive energy demand, it has been decided to lower the pressure on the national electricity grid by using more renewable energy. The Vietnamese government is now encouraging companies, organizations, and households to acquire renewable energy technologies such as solar panels and wind turbines. This is expected to bring positive effects to Vietnamese electricity industry in the next few years, making renewable energy usage more convenient and familiar for people. [8.]

2.2 GreenViet Consultancy and Alpes GDB

GreenViet green building consultancy, located in Ho Chi Minh City, is currently one of the most famous green building consultants in Vietnam that provides green building certification, energy and water audits, commissioning, green building training, and design optimization. As an active member of green building councils such as USGBC, SGBC, and VGBC, GreenViet uses LEED (U.S.), Green Mark (Singapore), and LOTUS (Vietnam) assessment tools. The company has taken more than 50% of Vietnamese green building market. It has consulted and completed over one hundred projects in Vietnam and within the Southeast Asia region. [9.]

Figure 2. Front façade of GreenViet (left) and ALPES building (right)

Alpes Green Design & Build, located in Da Nang City, specializes in sustainable architecture with services for houses, apartments, offices, hotels, resorts, and educational facilities. The company was founded with a future mission of bringing a real green living space, contributing in making the city greener. Professional workflow, creative-thinking designers, and skilled workers are the main factors that make Alpes's clients satisfied. [10.]

Alpes has participated in architecture competitions in various countries such as Vietnam, the Netherlands, and Hong Kong to introduce itself as part of Vietnam architecture. The office of Alpes is sustainable and stunning, as demonstrated in figure 2. The building, known as the modern village office", has been awarded several national and international prizes:

- 18 World's Fantastic Permeable Facades - Archdaily (US) [11.]
- Futurarc Green Leadership Award 2018 – BCI Asia [12.]
- Green Building for Workers - Vietnam Central Propaganda Organization [13.]
- One of The World's Best Offices 2018 – GOOOOD Hong Kong Magazine [14.]
- WAF Shortlist 2018 – World Architecture Festival. [15.]

3 Design & Construction

The Alpes office building has four storeys and it is located in Da Nang city, central Vietnam. The 350 m^2 building was designed by Alpes architects and constructed in 2016. The front façade is facing southeast with a deviation angle of 22^o towards the east direction. Unlike the old office architecture that consumes a large amount of energy for air conditioning and artificial lighting, the Alpes building design and construction follow the green buildings trend to save energy and create a feeling of a peaceful and homely workplace. Alpes building's sustainable architecture aims at energy efficiency, reducing the harmful effects on the environment to a lowest possible level. The design utilizes the properties of window and sliding glass door systems to achieve passive daylighting. In addition, semi-open facades combined with proper shading systems such as vertical sunshades and green walls, also increase daylight penetration. As a result, the level of indoor lighting has been effectively increased.

Building Materials

The building uses simple materials produced from natural and local sources, which are both safe for the users and environmentally friendly, to reduce the emission of greenhouse gases to the environment and to minimize the amount of waste that could cause environmental pollution. For example, AAC bricks known as autoclaved aerated concrete or autoclaved cellular concrete, were used for structural and thermal resistant purposes of both the interior and exterior structures (figure 3). This material is lightweight and highly durable compared to other traditional clay bricks in Vietnam. [17.] Moreover, perforated bricks were used for parts of walls where were possible for natural ventilation and cooling.

Figure 3. AAC bricks used in Alpes building construction [46.]

Not all wall surfaces in the Alpes building are painted to have a simple and natural look of the structure and, especially, to eliminate toxic chemicals from the paints and paint production, which have negative effects on the users and the environment. Furthermore, high quality glass window and door products were used as described in chapter 3.3 below.

Compactness

The shape and size of a building have a significant impact on its energy consumption. Cooling and heating demands of a building are partly influenced by its compactness ratio. This quantity is determined by the SA/V ratio, where SA is the surface area of the envelope of the building and V is the volume of the building. A smaller surface area leads to less heat transfer (figure 4). For small single-story buildings or single-family houses, the compactness ratio usually ranges from 0.7 to 1 m^2/m^3 (or m^{-1}) while this index is from 0.3 to 0.7 for multi-story buildings. [18.]

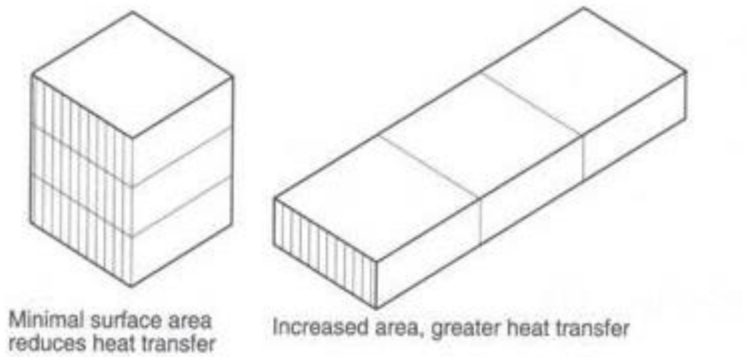

Figure 4. Buildings with different shapes lead to different heat transfer [18.]

In a hot humid climate zone like Vietnam, a large surface area will lead to much heat gain through it. Therefore, the ratio should be as low as possible to minimize heat gain. To be more specific, a cost-effective compactness ratio for a small domestic building should be smaller than 0.7 m^2/m^3. The structure of the Alpes building is similar to that of a three-story tube-house which is a particular shape of house or building in Vietnam. [19.]

$$Compactness\ ratio = \frac{Surface\ Area}{Volume} = \frac{756.3\ m^2}{1{,}222.8\ m^3} = 0.62\ m^{-1} \quad (1)$$

The surface area of the Alpes building is 756.3 m^2 and its total volume is 1,222.8 m^3 (table 1). The building has an ideal SA/V ratio of 0.62 (as revealed in formula 1), implying the heat gains for this tube-shaped building are smaller than those in conventional buildings.

Table 1. Areas and volume of Alpes building

Southeast façade (m^2)	61.5
Southwest façade (m^2)	229.8
Northwest façade (m^2)	61.5
Northwest façade (m^2)	229.8
Roof (m^2)	67.7
Base floor (m^2)	106.0
Total surface area (m^2)	756.3
Building Volume (m^3)	1,222.8

3.1 Green Space

The architects designed the Alpes building starting with the idea of an eco-friendly modern village office, bringing the feeling of an old village to an urban area, and creating a garden space for employees. The intention was to keep the existing vegetation and add other types of plants based on their adaptability to the climate of Da Nang city, such as bamboo, banana tree, and pampas grass, many of which were already present in the plot before the planning was initiated by Da Nang City Council. The biological system was then combined with the structures of the Alpes building to recreate a green and environmental friendly workspace for workers as seen in figure 5. Moreover, the surrounding vegetation works as a coating layer, preventing the afternoon heat from affecting the building's thermal comfort. [20.]

A lot of attention and time was invested in the green roof system. This type of roof brings numerous sustainable benefits to the building as it

- absorbs greenhouse gases
- absorbs air pollution and dust
- retains water in order to reduce stormwater runoff
- stores rainwater for irrigation and other possible uses
- prevents direct solar radiation that directly heats the building, surrounding land as well as the indoor air
- insulates heat to minimize the energy demand for active cooling. [21.]

Figure 5. Alpes workspace surrounded by plants [47.]

A nearly 70 m^2 area of the roof is covered by white pampas grass (figure 6). Before the grass was planted, the roof underwent a strict waterproofing process applied during the construction. After the waterproofing had been completed, a drainage system was installed using plastic drainage cell to cover the surface of the concrete roof. Geotextile fabric was then used to control erosion and maintain the stability of the soil. The final step was to add the soil for plants.

Figure 6. Green roof of the Alpes building [47.]

In addition, an automatic irrigation system was applied to serve the green roof and green walls because of its convenience. The water is directly pumped from the building's water line, channelled to the roof and distributed to the plants of the green walls. In the future when Alpes GDB has a further development, a harvesting system could be a proper innovative idea to optimize the use of rainwater. A water harvesting system includes a roof catchment water system and a water pipeline system. Rainwater is caught from the roof, led into a filter system that filters out the contaminants, and finally into tanks or cisterns. From the tanks the water can be pumped to sinks and taps. Furthermore, water can be reused to irrigate plants. [22.]

3.2 Climate Data

Da Nang is located in central Vietnam where the climate type is tropical monsoon with two seasons: dry season (January – August) and wet season (September - December). Normally, the temperature between June and August is at its highest, ranging from 28^{o}C to 30^{o}C, while the lowest temperature is between December and February, ranging from 18^{o}C to 23^{o}C. [23.]

In the provinces and cities of the same area, the sun seems to shine throughout the year, even in the rainy season. Except for the rainy days, 90% of the days in a year can provide solar energy for all purposes. In this region, the average number of sunshine hours ranges between 2,000 – 2,600 hours/year and the amount of solar radiation is 20% higher than in the North. [24.]

3.3 Windows, Doors and Shading

3.3.1 Windows and Doors

Vietnam is located in a hot and humid climate region in the northern-eastern hemisphere, and by installing a 27.4 m^2 window system on three sides of the building, the Alpes building is able to receive a considerable amount of natural light. This minimizes the use of artificial light. The window and glass sliding door system of aluminium works effectively to provide protection against exterior heat and noise. The southwest-facing windows of the building are installed next to grey and white brick wall textures with rows of protrusive bricks for blocking heat as well as for decorative and aesthetic purposes (figure 7).

The types of windows used in the building are fixed windows to let in the light and add expansive view, and openable windows for natural ventilation and cooling. Because the southeast and southwest facades receive a large amount of sunlight, seven out of fourteen windows positioned around the building are on the southwestern wall. Northeast façade, considered to have the least natural light, has no window installed. Systems of glass sliding doors are also installed on these two facades since the prevailing wind blows from the same directions. [24.]

Figure 7. Southwest façade of the building [47.]

As a result of the southeastern and southwestern windows and glazing doors, the Alpes building receives plenty of natural daylight for all workspaces in the building. That leads to a reduction of lighting demand during office hours. Compared to conventional aluminium windows and doors in Vietnam, the better-quality products bring a contribution to thermal insulating solutions. The product lines used in the building are of single-glazing type, specially designed for the Southeast Asia market, based on the environmental studies on the region's climate and weather conditions, lifestyles, and current demands. [25.] An advantage of choosing these windows and doors products is that Alpes distributes them. The window manufacturer YKK AP and Alpes GDB have a collaborating relationship with the same goal towards sustainability. As the local distributor, Alpes can select the most suitable products for the building. Unfortunately, information concerning product specifications, such as U-values and g-values which might give a better understanding of how good the products are, was not available for the thesis.

Figure 8. Ventilation window on northwest façade [47.]

The YKK AP sliding doors together with both fixed and openable windows were chosen to make the best use of the weather conditions of Da Nang city. Ventilation windows (figure 8) are used on the northwest walls while both openable and fixed single-glazing windows are installed on the southwest walls (figure 10). The technical properties of the products such as air tightness, sound isolation, and wind resistance are superior to those of other Vietnamese glass products. The designed air tightness satisfy the requirements of the current standards in Japan and the U.S.A. To seal the windows and doors, a rubber pad is placed between the connecting parts of the windows and doors, creating the tightness between frames and wings. In the same way, a rubber pad is placed between the different parts of the windows and doors to create the tightness between the parts. Hence, the air exchange between outside and inside atmosphere is minimized when the doors and windows are closed, and the maximum energy saving efficiency is obtained. [25.] In fact, air tightness is not thoroughly used since occupants often open the windows, and the vertical sunshades on the front facades let the air into the building all the time.

The protective functionalities and thermal properties of the YKK AP windows and glass doors were verified for compliance with the Energy Star and ASTM (US) building standards for window and doors. The energy efficiency insulating glass with low-E (low emissivity) coating blocks a high percentage of the heat gain, and minimizes infrared and ultraviolet (UV) transmission. Moreover, the low-E glass does not minimize the amount of light entering the building, ensuring the brightness of the working space. The low-E coating reflects the warm air back inside, and keeps the building temperature in the thermal comfort zone. [26.]

Soundproofing criteria of YKK AP products follow the Japanese standards. Thanks to the high air tightness, the aluminium window and door structures are able to reduce the noise from the outside by 25 to 30 decibel (dB) [25.], keeping the noise level inside the building at 40 to 50 dB, which is ideal for office buildings. [27.] Actual tests have illustrated that YKK AP windows and doors products have the ability to withstand wind and storm pressure up to a speed of 50 m/s, which is equivalent to the wind speed at level 11 in Vietnam. [28.]

3.3.2 Shading

Having windows and glazing doors in all directions except northeast, solar shading is a noticeably important factor of the Alpes building. They limit the heat gain from the sun and reduce the cooling costs of the building. [29.] Within the working space, shading is provided from different sources such as window overhangs, interior shading devices, exterior green walls, and sunshades. The shading system of Alpes mainly includes a green wall system on the southeastern, southwestern, and northwestern facades, and vertical sunshades for the southeastern and southwestern walls (Appendix 1: 2/13).

The northeastern side of the building is an AAC brick facade without any windows. The green wall system used appears to be an ideal solution for reducing the overall temperature inside the building without obstructing the sunlight coming into the workspace. Furthermore, the surrounding vegetation is also considered an effective method for the purpose of blocking the afternoon sunlight. For example, bamboo bushes and banana trees are tall enough to obstruct the low-angled-sun from the east and west during the summer. Besides cooling the air, the plants also capture the CO_2, purify the air, and add the biodiversity to the green space of Alpes building. [22.]

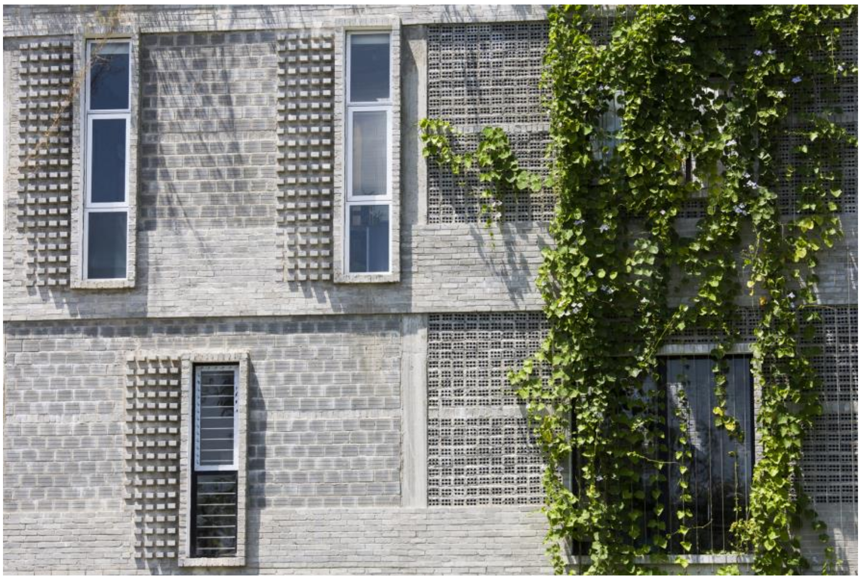

Figure 9. Windows with decorative slats and green wall on the southwest façade [47.]

With the same purpose, manually operated internal shading blinds were installed to prevent excessive sunlight penetration but still ensure enough natural light being let in. The interior shading device allows periodical maintenance, convenient control, and fast movability. Moreover, concrete vertical sunshades were designed to be combined with the surrounding plants for providing proper shading. This type of a shading system is becoming more popular for new building designs because of its sun control property and aesthetics. Vertical sunshades are believed to be the most effective for east-west elevations of buildings in general and southeast-southwest elevations of Alpes building in particular. [29.]

3.4 Ventilation

Together with climate and shading, natural ventilation is also considered as a factor in the feasibility of a near-zero energy building's feasibility. [4.] The Alpes building has an ideal location near the beach with the wind blowing continuously, which is an advantage for solutions based on the natural conditions. Because the thermal comfort zone for most of the Vietnamese people ranges from 24ºC to 29ºC, [30.] passive designs such as natural ventilation and natural cooling were deemed suitable for the Alpes building. It is possible to obtain a high air change rate, meaning the air is supplied and removed continuously without a mechanical system. Fresh air coming nonstop into the building helps to maintain satisfactory internal comfort conditions.

It is possible to cross-ventilate the building by opening windows on the northwest facade and glazing doors on the opposite site of the building. The design of this natural cooling method is based on wind research and simulation that improves the indoor air quality and moderates the indoor temperature.

Figure 10. Brick holes create natural ventilation for the Alpes building

On the other hand, the ventilation openings on the walls can let heat enter the building. This is prevented with decorative slats and exterior vegetation on the southwestern façade in order to utilize their thermal insulation effect. Consequently, decorative slats and exterior green wall prevent the external environmental effects and provide natural ventilation, making the Alpes building cool all the time. Moreover, fresh air from the sea is led into the building through the brick holes (figure 10) with a comfortable temperature.

3.5 Cooling

Passive cooling

Heat enters a building through the thermal envelope such as roof, walls, windows, and doors. Passive cooling techniques minimize daytime heat gains and balance the temperature of a building with natural methods, such as air flow, natural wind, and evaporation. Having some certain advantages such as energy efficiency and cost-effective, this type of cooling techniques are part of the passive design of the Alpes building. They help in keeping the working space comfortable throughout the hot summer without using the air conditioning system as in conventional buildings. Undoubtedly, this is the most economical and suitable solution with the least impacts to the environment for the Alpes building. [31.]

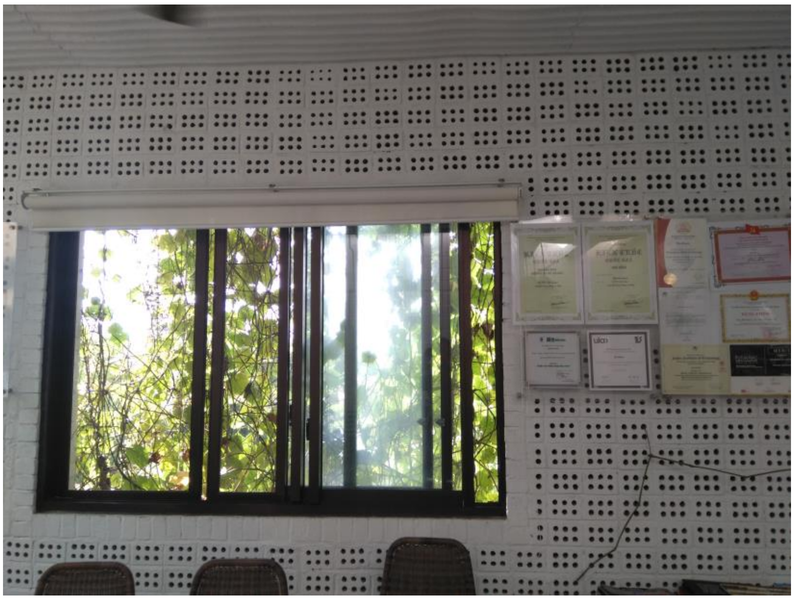

Figure 11. Hollow bricks were creatively placed for passive cooling

To describe the Alpes building in a little more detail, a part of the southwestern brick wall was built in a creative way with 90^{o} angle brick laying (figure 11) in order to let fresh air flow into the building. It was concluded that this type of wall facing southwest would not have any serious problems with rainwater and moisture. Furthermore, the building has no type of thermal insulation, as the windows and doors, being open most of the working time, are effective in cooling the building. Plants of an ideal height, might be the major reason why the building is not too hot during summer. The plants provide sunshade against the low-angle sun for the southwestern and southeastern facades.

Active cooling

Modern Vietnamese buildings are fitted with air conditioning systems, such as VRV (Variable Refrigerant Volume) or VRF (Variable Refrigerant Flow) (figure 12). These cooling technologies are well known and widely applied because of their aesthetic, high COP (coefficient of performance), and other energy saving properties. [32.]

The design of the Alpes building, however, aimed at a building that would not need any complicated cooling systems, only fans. In fact, the lowest interior temperature of the building recorded during the winter is 23.5°C. Similarly, the highest interior temperature within Alpes building is 31.1°C. Those are considered as acceptable indoor temperatures in an office building in Vietnam and especially in Da Nang city. It is worth noting that winter in Da Nang is not as cold as in other areas, therefore, a heating system during the winter is unnecessary.

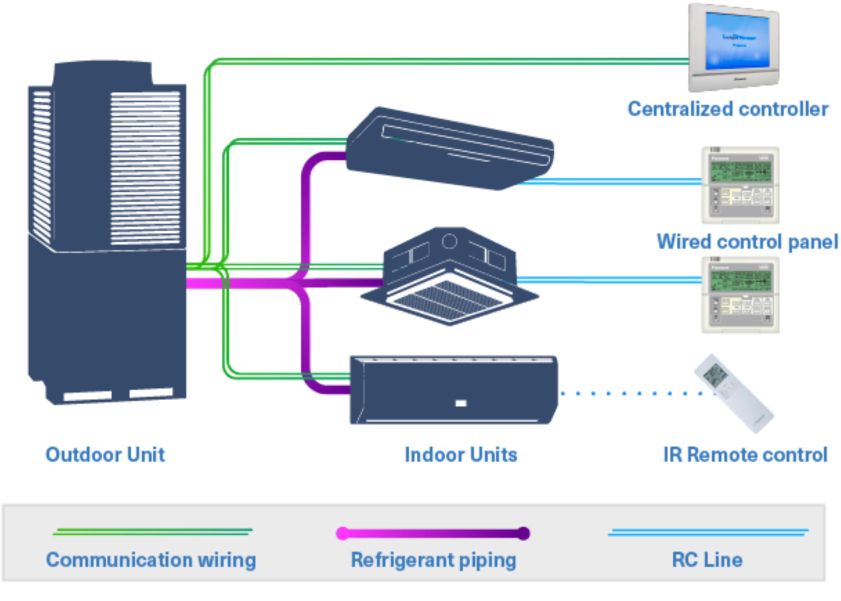

Figure 12. Scheme of a VRF (Variable Refrigerant Flow) system [32.]

The cooling system of the Alpes building consists of a central fan system for the whole building and ceiling fans in each room. Unfortunately, at the time of data collection for this study, the central fan had been sent to the manufacturer for maintenance, and no further information about it was available. Taking advantages of the natural cooling effect, the central fan is mainly only used during the hot summer. Ceiling fans create air movement, which removes heat and humidity from the human skin. In addition, the green roof and surrounding plants play a major role in cooling down the interior floors, leading to less active cooling demand.

4 Energy Solution

4.1 Water Distribution

The water system of Alpes building consists of water storage and water distribution, making it an indirect system which is quite popular in Vietnam. [34.] The storage includes two water tanks which each have a capacity of one thousand litters. The dimensions of the tanks are about 1.5 meters by 1.0 meter, meaning an area of at least 3 m^2 is needed for them. Therefore, they are located on the roof of the building to make the best use of the empty roof area. Also, placing water tanks on the flat surface of a solid concrete roof ensures enough load bearing capacity. The water distribution is done with a water pipeline system that connects the local water source with the tanks and sinks. From the local water line, water is pushed into the two tanks for storing purposes using a pumping device. The water is then channelled from the tanks to sinks or water taps for daily use.

Figure 13. Kangaroo water purifier KG109 KNT [33.]

An indirect water system has some advantages compared to the direct system that does not use any storage components. For example, transportation and installation costs are not expensive and the ability to store a large volume of clean water during the dry season from January to August is certainly necessary. This could be explained that water demand is high during the daytime, leading to low water flow rate from the taps. Therefore, storing water can ensure the occupants have enough water to use. Each tank also has a small electric float to control the water level and prevent the water from overflowing when the tanks are full. The float uses the water level to switch conditions. The float is placed at a permanent position inside the tanks and when the water level reaches the position, the system will send a signal to switch the pump off immediately. [34.]

The water system of the Alpes building does not provide potable water since it does not have any filters or filtering components. For this reason, Kangaroo water purifier KG109 KNT (figure 13) is used to supply clean drinking water. The product, made in the USA, uses NANO Silver technology to remove bacteria from the water line. The machine contains nine filters for different filtering purposes. The core of the filters is composed of mineral rocks and antioxidants which contribute to the prevention of diseases. [33.] The function of each filter is described in table 2 below.

Table 2. All types of filters of a Kangaroo water purifier KG 109 KNT [35.]

1	PP 5µm (Polypropylene)	▪ filter organic impurities, debris, sediment or suspended particles in water larger than 5 microns
2	Activated Carbon	▪ remove pollutants in the water by absorbing them
3	PP 1µm (Polypropylene)	▪ remove suspended particles larger than 1 micron in water (silt, sand, etc.) ▪ remove some algae ▪ protect the RO* membrane from obstructed dirt
4	RO Filmtec (USA) (Reverse Osmosis)	▪ use special material to create 0.0001 micron clearance, removes solids, heavy metal ions, microorganisms, bacteria, viruses and organic substances ▪ make water pure
5	Nano Silver	▪ remove bacteria
6	Ceramic	▪ remove bacteria
7	Alkaline	▪ increase PH, alkaline water to neutralize excess acid in the body
8	Maifan natural stone	▪ supplement natural properties and minerals for the water, enhance body resistance
9	ORP (Oxidation Reduction Potential)	▪ produce the right pH and electrolytes to become the ideal drink for the body ▪ prevent aging, detoxify the body, enhance immunity, prevent cancer

4.2 Electricity - Photovoltaics

The Alpes building does not have any demand for domestic hot water, heating or active cooling. Moreover, the demand for artificial lighting is minimal, thanks to the passive daylighting achieved. Therefore, the energy consumption of the building is not too big. Based on the actual energy consumption, the Alpes building consumes about 1,000 kWh of electricity per month. According to the occupants of the Alpes building, computers and office equipment use most of the energy. [47.] The target is to minimize the energy consumed from the grid and use renewable energy instead. Due to the unstable wind conditions, solar power is the most suitable renewable energy source for the Alpes building, given that Vietnam benefits of a relatively huge and stable amount of solar radiation annually. [24.]

An on-grid solar power system was designed for the building. The system reduces the environmental impacts and compensates for the energy demand of the Alpes building, contributing to the near-zero energy building goal. The photovoltaic (PV) system will be installed on the roof of the building, reducing the use of electricity from the grid, while the energy produced but not directly used in the building will be fed into the grid. The result can be a near zero electricity bill and a turn to use solar energy, a sustainable and renewable energy source.

4.2.1 Design & Selection

Design

A 3D simulation model of the Alpes building was created using SketchUp drawing software, with the photovoltaic panels placed on the roof as shown in figure 15. As mentioned above in the previous chapter, the monthly energy consumption of the Alpes building is 1 MWh, equivalent to 12 MWh annually.

The PV system was planned to provide electricity for the Alpes building, with the excess sold back to the grid. The solar panel system was to cover the whole roof, to have a total power output of about 10 kWp (kilowatt peak), which produces nearly 14 MWh of electricity annually. In addition to covering the building’s energy usage with the solar panels, the excessive energy generation could also benefit the Alpes company since one of the policies of the Vietnamese government is to purchase this type of energy from companies and households to encourage the use of renewable energy. [37.] With an estimated annual production of 14 MWH of electricity, 12 MWH of electricity will be directly used in the building, and nearly 2 MWH of electricity will be fed into the grid.

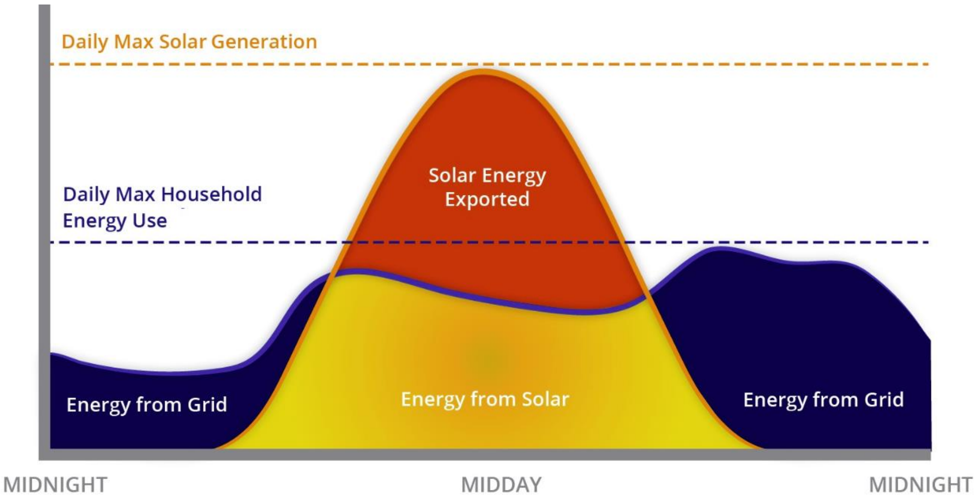

Figure 14. Energy consumption (C) and solar energy production [38.]

The graph in figure 14 explains the solar energy consumption of the Alpes building. The red and yellow areas indicate daily solar energy production while the blue area indicates the daily energy use of the Alpes building. The yellow area illustrates solar energy consumed in the building while the red area is solar energy sold to the grid. The blue area alone is the energy Alpes consumes from the grid. Hence, the energy purchased from the grid (blue area) is the difference between the total consumption (areas below the blue line) and the solar energy used (yellow area). [38.]

Figure 15. 3D model of Alpes building [47.]

Based on the drawings of the roof of the Alpes building, the photovoltaic panels will be installed on the back half of the 67.7 m^2 roof area in order to optimize sunlight harvesting. The angle of inclination is 11^o-15^o from the horizontal, considered highly efficient and suitable for a fixed PV system frame. The deviation from the south is 22^o since the system faces southwest (figure 15). This is considered an optimal design to both fit the roof structure and receive as much sunlight as possible.

The solar power system includes multiple photovoltaic panels, an on-grid inverter, and a rack system for the photovoltaic panels. The design follows the building standards applied by GreenViet Consultancy on current energy projects, as well as the requirements set by the Alpes Green Design & Build company:

- Solar panels will be installed either on the roof or in the place that gets most sunlight during the day in order to optimize sunlight harvesting.
- The selected on-grid inverter and the electronic devices are designed and made with switching technology and advanced micro-processing technology, possibly connected to the computer.
- An electricity meter is used to measure the harvested and consumed energy.

The devices mentioned above will transform the harvested solar energy and convert the direct current (DC) into alternating current (AC) with a frequency of 50 Hz and voltage of 220V, directly connected to the grid. The on-grid power system will work automatically to switch the PV system off when it is dark or when the grid power connection is lost because of storms. The system does not make any noise while operating and it is easily installed in any position and place. The solar energy will be either used in the building (SC) or fed (S) into the grid. Since it does not use any batteries, no battery maintenance will be needed. This type of an energy system is used in several projects of GreenViet, and it is considered safe and economical for the Alpes building.

Operating description

When the conditions are dark or cloud, PV panels will not produce electricity, and the Alpes building will get the electricity from the grid. When there is sunlight, the PV panels will produce the electricity, and the grid inverter will automatically convert the DC from the solar panels into AC with 50 Hz frequency, same phase and voltage as the grid.

The system will be designed to work under certain weather and grid conditions:

- When the building requires more electricity than is available from the PV system, electricity from both the grid and the solar system is used.
- When electricity need of the building is equal to the production capacity of the PV system, the building only consumes electricity from the solar system.
- When the building requires less electricity than is produced by the PV system, the surplus electricity is fed to the grid.

The frame system would be installed on the roof on galvanized steel structures. An epoxy paint would be used to provide the steel frame with a protective coating against water, corrosion and severe weather conditions. The parts would be connected by welding following requirements of Vietnam standard TCVN 1691-75 for welding.

System selection

The panel model was selected by the author based on the size of the building's roof, as the total area of the panels fits roof area of the Alpes building. The product that was selected is IR305P-72 with a maximum power of 305 W and a lifespan of up to 25 years, as shown in table 3. The system was sized so that almost 100% of the energy consumption would be covered with solar energy.

Table 3. Solar BK photovoltaic panel IR305P-72 specifications [39.]

Manufacturer	Solar BK (Vietnam)
Product Code	IR305P-60
Cell Type	Polycrystalline
Maximum Power	305 W
Maximum Current	9.33 A
Maximum Voltage	32.69 V
Dimensions	1,640 x 990 x 35 mm
Weight	19 kg
Lifespan	25 years
Module Efficiency	18.8%
Whole System Efficiency	80%
Inverter Conversion Efficiency	95%

The design has a 53.6 m^2 PV system which consists of 33 solar panels with a total power of 10,065 kWp. The dimensions of the panels are 1,640 mm, by 990 mm, by 35 mm. The permanent steel framing system is oriented towards the southwest and positioned above the roof surface to leave enough space for the water tanks (figure 15). Moreover, the maintenance method and the safety of the maintenance worker are also considered in the design process.

The inverter is one of the most important components of a photovoltaic system, along with the modules. The Senergy SE 10 KTL Series grid-tied inverter (figure 16) whose output is 10 kW, will be connected to the PV array on the roof of the Alpes building. This product line is compliant with both residential and small-scale business standards. Other considerable advantages are that it is lightweight and small, with easy and convenient installation, and multiple control methods via phones and monitors. [40.]

Figure 16. Senergy SE 10 KTL Series inverter [40.]

The inverter is equipped with highly intelligent maximum power point tracking (MPPT) to maximize power extraction. [40.] The algorithm follows the output of the photovoltaic module, compares it to the system voltage and determines the best power that the panel can produce. In other words, this technology tracks the point with the maximum power voltage (peak voltage) which varies according to solar radiation, the temperature of the cell, and the ambient temperature. [41.]

Since the solar power system works simultaneously with the grid, spike loads or voltages from the power lines and sources cannot impact or damage the system. The lifetime of the system and its electronic components could be from twenty to thirty years or longer, depending on the working conditions. There is no need for batteries because solar radiation is basically available all year round, and office work is mostly done during the midday hours. Also, the Vietnamese government has a policy stating that the Electricity of Vietnam (EVN) pays, a reasonable price of 9.35 US cents/kWh for the solar energy fed into the grid. [8.]

4.2.2 Energy Calculations

The amount of energy that the PV panels could produce is calculated by knowing the solar insolation of Da Nang city. Under the best conditions, it was calculated that the building could exceed the near-zero limit, making itself a net zero energy building.

System’s total power

305 Wp/panel x 33 panels = 10,065 Wp = 10.065 kWp (2)

Annual production:

10.065 kWp x 1,387 kWh/kWp = 13,960 kWh/year (3)

According to the photovoltaic energy potential map in appendix 4, the generating rate in Da Nang city is about 1,387 kWh/kWp, meaning the PV system with 10.065 kWp power will be able to produce 13,960 kWh of energy each year (formulas 2 and 3).

Table 4. Outputs of PV system

Production	13,960	kWh/year
Consumption	12,000	kWh/year
Sale	1,960	kWh/year

With an annual production of 13,960 kWh and an annual consumption of 12,000 kWh, Alpes would be able to sell 1,960 kWh back to the grid each year (table 4 above). The costs for the whole photovoltaic system, purchasing energy from the grid and the price for selling the generated renewable energy back to the grid are calculated and shown in the next part of the thesis.

4.2.3 Economic Calculations

Economic calculations were made by the author to figure out the final cost of the whole system and to provide a quotation for the owner of the Alpes building. All costs, including energy cost, prices of system units, and technology costs were local ones from previous similar energy projects. The costs were then converted from Vietnamese dongs (VND) to US dollars (USD) for a better understanding, with a currency rate of 23,395 VND/USD.

The unit price for a photovoltaic panel system in Vietnam is 1.1 U.S. dollars per watt-peak (USD/Wp), meaning that a system of 33 solar panels at 10.065 kWp costs about 11,000 USD (formula 4).

The cost of the 10.065 kWp power PV system:
1.1 USD/Wp x 10,065 Wp = 11,072 USD *(4)*

The cost of the inverter was determined to be approximately 1,300 USD by directly contacting the local product distributor in Ho Chi Minh city since this information was not published online. Consequently, the PV system for the Alpes building costs a total of almost USD 12,400 as shown in table 5. This is the final estimated cost since the costs of other electrical equipment, metal support, and installation of the system are already included according to GreenViet electrical engineers. [48.]

Table 5. Estimated costs for the whole PV system

System Power (kWp)	**Unit Price (USD/Wp)**	**Whole System (10.065 kWh) (USD)**	**Inverter (USD)**	**Total Cost (USD)**
10.065	1.1	11,072	1,282	12,354

The periodical electricity cost is analysed on the basis of the current energy cost and energy retail price of the electricity corporation EVN for different customer groups. [42.] EVN has different prices for different levels of consumption as described in table 6. With a consumption of 1,000 kWh, the monthly expense of Alpes building for the electricity is around USD 105.

Table 6. Monthly electricity expense of Alpes building calculated based on EVN prices [EVN.]

Group (kWh)	Unit price (USD/kWh)	Consumption (kWh)	Cost (USD)
Tier 1: 0 – 50 kWh	0.066	50	3.311
Tier 2: 51 - 100 kWh	0.068	50	3.420
Tier 3: 101 – 200 kWh	0.079	100	7.942
Tier 4: 201 – 300 kWh	0.100	100	10.002
Tier 5: 301 – 400 kWh	0.112	100	11.178
Tier 6: 401 – above kWh	0.115	600	69.271
Total		**1,000**	**105.123**

To summarize, Alpes would be able to sell 1,960 kWh back to the grid each year. This is highly encouraged by the Vietnamese government for a sustainable future of renewable energy use. The selling price was officially regulated at 9.35 US cents/kWh. [8.] Therefore, the annual benefits of the solar panel system to Alpes include a saving cost of 1,000 kWh of electricity and the amount of money from the sale of 1,960 kWh, as shown in formulas 5 and 6. Eventually, the total annual economical benefit could be up to more than USD 1,400 as calculated in formula 7.

Annual energy expense that could be saved:
105.123 USD/month x 12 months/year = 1,261.5 USD/year *(5)*

Annual amount of money earned by selling energy to the grid:
0.0935 USD/kWh x 1,960 kWh/year = 183.26 USD/year *(6)*

Total benefits from PV panel system:
1,261.5 USD/year + 183.26 USD/year = 1,444.76 USD/year *(7)*

According to table 5 and formula 7, the estimated cost of the investment is USD 12,354 and the financial benefit is USD 1,444.76 annually. Simple payback time is then calculated in formula 8, without consideration for interest rate. This quantity varies according to economic factors such as the energy price variation, energy increase rate, interest rate, and inflation rate. The simple payback time is determined to be around eight and a half years, meaning it would take that time to recover the investment of the whole photovoltaic panel system.

$$\frac{Total\ investment\ (VND)}{Total\ savings\ (VND)} = \frac{12{,}354\ \text{USD}}{1{,}444.76\ \text{USD}} = 8.5\ years \qquad (8)$$

According to GreenViet’s electrical engineers, this is a short payback period for a small-scaled PV system with a system power of about 10 kWp, provided that the design has been optimized and well done. It is possible to launch the nZEB project with a reasonable initial investment for the whole solar power system. On the other hand, the cost of the solar panels which makes up a high percentage of the investment tends to decrease in Vietnam, this can be seen as an advantageous factor for launching and mobilizing the wide community sources, aiming to the sustainable development.

5 LOTUS Green Building Certification

LOTUS is a green building certification system for the built environment within the Vietnam region, created and developed by the Vietnamese Green Building Council. This green building assessment and rating tool is based on well-known international green building rating tools, such as LEED, BREEAM, and Green Mark. LOTUS aims at:

- making standards and benchmarks for the Vietnamese construction industry
- making a guideline for an effective use of natural resources
- introducing and promoting environmentally friendly practices to the Vietnamese construction industry. [3.]

Similarly to other green building certification systems, LOTUS concentrates on assessing buildings on many categories such as energy, water, materials, health, comfort, waste and pollution. Each category has a different number of obligatory and optional credits with specific scores. The final rated score and rank of a building depend on the meeting of the requirements of LOTUS. Based on the credits and points achieved, the building can be ranked if it achieves a certain percentage of the total score. Buildings meeting at least 40% of the total amount of points are ranked as LOTUS Certified with LOTUS certification provided. In the same way, buildings achieving a minimum of 55%, 65%, and 75% of the total score receive a LOTUS certification for Silver, Gold, and Platinum levels, respectively (figure 17). [3.] At the end of 2018, the number of registered projects for LOTUS certification was 51 but only 21 projects had been certified. In 2018, 7 out of 13 registered projects received LOTUS certification. [43.]

Figure 17. LOTUS certification levels [3.]

The tool has been developed for all fields of construction with a suitable rating system for each field:

- LOTUS Non-residential
- LOTUS Buildings in Operation
- LOTUS Multi-family Residential
- LOTUS Interiors
- LOTUS Small Interiors
- LOTUS Small Buildings
- LOTUS Homes. [3.]

Vietnamese and international green building experts conclude that with design and construction following LOTUS, buildings are able to save up to 40% and 50% of energy and water consumption, respectively. Simultaneously, high indoor air quality, health, and comfort are maintained as building spaces are better ventilated and more natural lighting is provided. [44.]

Alpes Certification Process

The Alpes building can get some points according to the LOTUS system while others are not possible to achieve. As the green building consultancy, GreenViet is responsible for guiding the Alpes through the process of registering for LOTUS, as well as for requesting the necessary materials from the building owner. The Alpes building seems to meet all the requirements of certain credits to obtain the maximum score.

The Alpes building is assessed according to the LOTUS Homes system since it has a similar shape as a three-story tube-house. An initial assessment is based on the study of the building and the LOTUS user tool. This excel tool uses a system of four main directions: East, West, South, and North. The direction facing of the facades is defined as the facades oriented within the range of 45° to the direction (figure 18). For example, an east facing façade in the LOTUS tool means that the deviation angle could vary within 45° towards north or south. The main facade of the Alpes building is facing southeast with a deviation angle of 22° to the east. Since the deviation angle is smaller than 45°, the input data for the Alpes building orientation is selected as east for the most relevant outputs. As a result, the facades facing southeast and southwest are treated as eastern and southern façades in the LOTUS user tool.

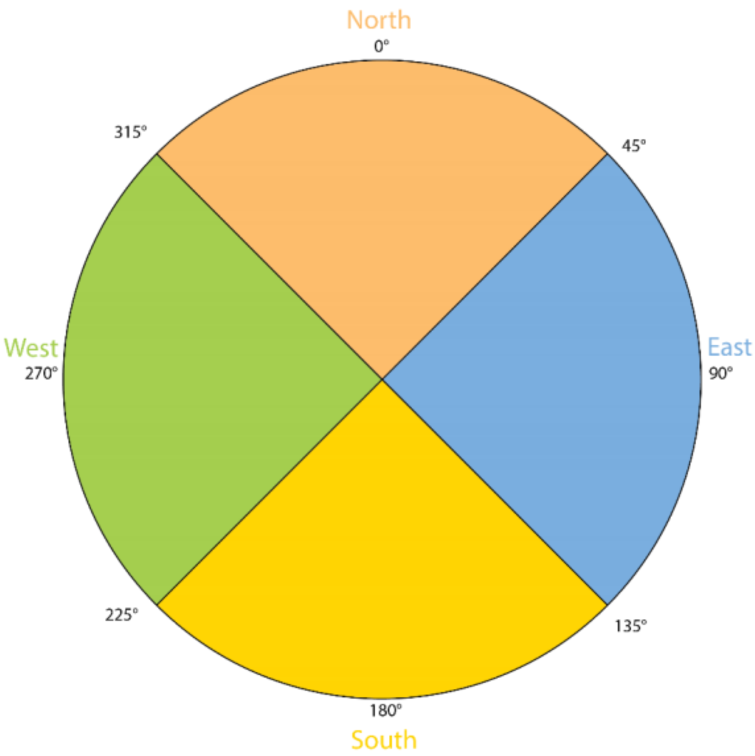

Figure 18. Definition of the different facing facades [45.]

Energy

The energy category aims at monitoring and reducing the energy consumption of a building. This can be done, for example, through passive design, the use of natural ventilation and the installation of energy-efficient equipment, such as HVAC, lighting, and water heater. [44.]

The Alpes building can obtain a good score for several credits such as Passive Design, Home Cooling, and Artificial Lighting. In the passive design credit, it is possible to get all 5 points. First of all, the area of east and west facades of Alpes is about 21% of the total façade area (calculated in formula 9), lower than the 40% required by LOTUS. Secondly, the window-to-wall (WWR) ratio of the building's eastern and western facades is equal to 14% as in formula 10, satisfying the requirement that WWR of the east and west facades must be lower than 15% to get 2 points. Last but not least, an appropriate shading system installation with vertical sunshades (0.8 m x 2 m) and manual internal shading devices, able to cover 90% of the glazing area of the east and west facades.

$$\%\ of\ east\ and\ west\ facades = \frac{61.5\ m^2 + 61.5\ m^2}{582.6\ m^2} = 21.1\% \qquad (9)$$

$$WWR\ of\ east\ and\ west\ facing\ facades = \frac{13.8\ m^2 + 3.44\ m^2}{61.5\ m^2 + 61.5\ m^2} = 14.0\% \qquad (10)$$

Water

The aim of the water category is to reduce the water consumption of a building through the use of water-efficient fixtures, rainwater harvesting, water reuse or recycling and associated water saving measures, contributing to ensure more sustainable management of waste.

The LOTUS credit Water Efficient Landscaping requires users to either select plants to minimize water demand for irrigation or install a water-efficient irrigation system. In fact, the Alpes building performs better than expected with a reduction of 80% of domestic water used for landscaping, compared to benchmark consumption. This helps the building to get a maximum of 2 points in this credit. The requirements of credit Drinking Water are also met by installing a drinking water filtration system with a Kangaroo water purifier which is described in chapter 4.1.

The nZEB project is still ongoing with several difficulties determined. Lacking required materials seems to be the most difficult part during the preparation process and this delays the project progress. Before the construction of the Alpes building in 2016, the owner did not intend to register for a green building certificate. For this reason, proper materials concerning local sources, manufacture, and purchase of building materials and products were not prepared and archived. Alpes, in fact, can get points and credits in many categories thanks to its sustainable design and energy efficiency. However, the LOTUS online submission is now an obstacle for the project since it takes time to request the materials and product certificates and specifications from all the product manufacturers and contributors.

Innovation category, for example, rewards exceptional performance, and recognizes innovative features or initiatives which are not specifically addressed by LOTUS. This could be seen as an open category with extra points for high efficiency in all aspects. The green area of the Alpes building significantly exceeds 30% of the credit requirements. In more detail, credit Heat Island Effect of Local Environment category requires that 50% of the roof area can limit the heat island effect while the calculations for the Alpes building give the actual percentage of 80%. Despite that, the shortage of drawings and visual materials leads to zero points achieved for this credit. The same reason also causes trouble in other categories such as Water, Innovation, and Community & Management.

6 Project Difficulties

The first problem in the Alpes building nZEB project was to figure out how to totally waterproof the building with the vegetation on the concrete roof. Designers and workers had to be aware of possible oncoming problems, as well as about the fact that there would not be any chance to redo anything once the construction is complete. A strict waterproofing process was followed and proceeded, under careful supervision. Furthermore, the size of the plants and their position within the building were also a struggling topic. In central Vietnam, the northeast monsoon could damage trees with sizeable canopy, which would affect the building. The solution was to stable the trees with a tree protection metal fencing system.

As stated previously, the rain was predicted to cause no problem to the Alpes building during the design process. To a greater or lesser degree, rainwater could still be problematic and a reason for wall dampness. Therefore, to avoid a situation where rainwater goes through the brick holes, a wall water drainage combined with decorative gravel and stone (figure 19) was designed to let the water flow out of the rooms, to the green area outside.

Figure 19. Wall water drainage inside the Alpes building

During the preparation stage for the LOTUS assessment, GreenViet found out that Alpes does not have all materials and certificates which were needed for LOTUS submission. For instance, although plenty of images, photos, and technical drawings were available, the required materials to illustrate that the Alpes building was constructed with sustainable building materials were unavailable or still missing. Similarly, life cycle assessments (LCAs) of some products used in the building could not be provided. Consequently, this became a disadvantage for the Alpes building in getting points in some credits, possibly leading to a drop in the expected level of certification.

One of GreenViet's first intentions was to calculate the heat transmission value (U-value) through each part of the building, using PHPP (Passive House Planning Package) or

OTTV (Overall Thermal Transfer Value) calculating tool. These values could bring a more objective view of the Alpes building's heat gain and loss. However, the lack of product specifications had prevented the team from realizing the idea from the beginning.

7 Conclusion

In conclusion, the Alpes building nZEB project's outcome seems to be positive for both Alpes GDB and GreenViet Consultancy, with the following key elements that make the Alpes building fairly sustainable:

- The climatic design of the building helps to improve the working environment, and creates the sustainability.
- Building materials used for the construction are natural, simple, locally extracted, harvested and manufactured.
- The Alpes building demands less energy than other conventional office buildings. Heating is unnecessary while cooling demand seems to be low.
- The PV system will produce more energy than is consumed, and the surplus energy will be fed to the grid. The pay back time of 8.5 years is good for a small-scaled PV project.

Table 8. Final results for the PV project

System Power (kWp)	Total Cost (USD)	Production (kWh/year)	Consumption (kWh/year)	Sale (kWh/year)
10.065	12,354	13,960	12,000	1,960

The photovoltaic system of 33 panels has a system power of 10.065 kWp and it costs about USD 12,000. The annual production is 13,960 kWh while the consumption is 12,000 kWh. Surplus energy fed to the grid will be sold with a price of 9.35 US cents/kWh (table 8).

The thesis proved that it is possible to construct energy-saving buildings in a tropical country like Vietnam that has hot and humid climate conditions. There might be no need to install any hot domestic water, heating, and active cooling systems. Also, the building could meet the requirements of the LOTUS rating tool, making itself a LOTUS certified building.

Together, Alpes GDB and GreenViet Consultancy aim to have a baseline design for energy-efficient and environmentally friendly buildings in Vietnam. The positive results of this thesis could contribute to the Vietnamese construction guidelines for zero energy, near-zero energy, and low-energy buildings in both residential and industrial sectors.

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48 Dat, N. 2018, September. Meetings, interviews & discussions.

Appendix 1. The Alpes building

Figure 20. Northwest façade of the Alpes building

Figure 21. Southeast façade (with vertical sunshades) of the Alpes building

Figure 22. Northwest and southwest façades of the Alpes building

Figure 23. Southeast and southwest facades of the Alpes building

Figure 24. Southeast and southwest facades in the evening of the Alpes building

Figure 25. Green roof of the Alpes building

Figure 26. Green space of the Alpes building

Figure 27. Working area of the Alpes building

Figure 28. Working area of the Alpes building

Figure 29. Working area of the Alpes building

Figure 30. Working area of the Alpes building

Figure 31. Working area of the Alpes building

Figure 32. Meeting room of the Alpes building

Figure 33. Entertaining area of the Alpes building

Figure 34. Entertaining area of the Alpes building

Figure 35. Entertaining areas of the Alpes building

Figure 36. Entertaining areas of the Alpes building

Figure 37. Passive daylighting inside the Alpes building

Figure 38. Ventilation pipeline connected to the central fan inside the Alpes building

Appendix 2. Drawings of the Alpes building

Figure 39. Southwest elevation of the Alpes building

Figure 40. Southwest section of the Alpes building

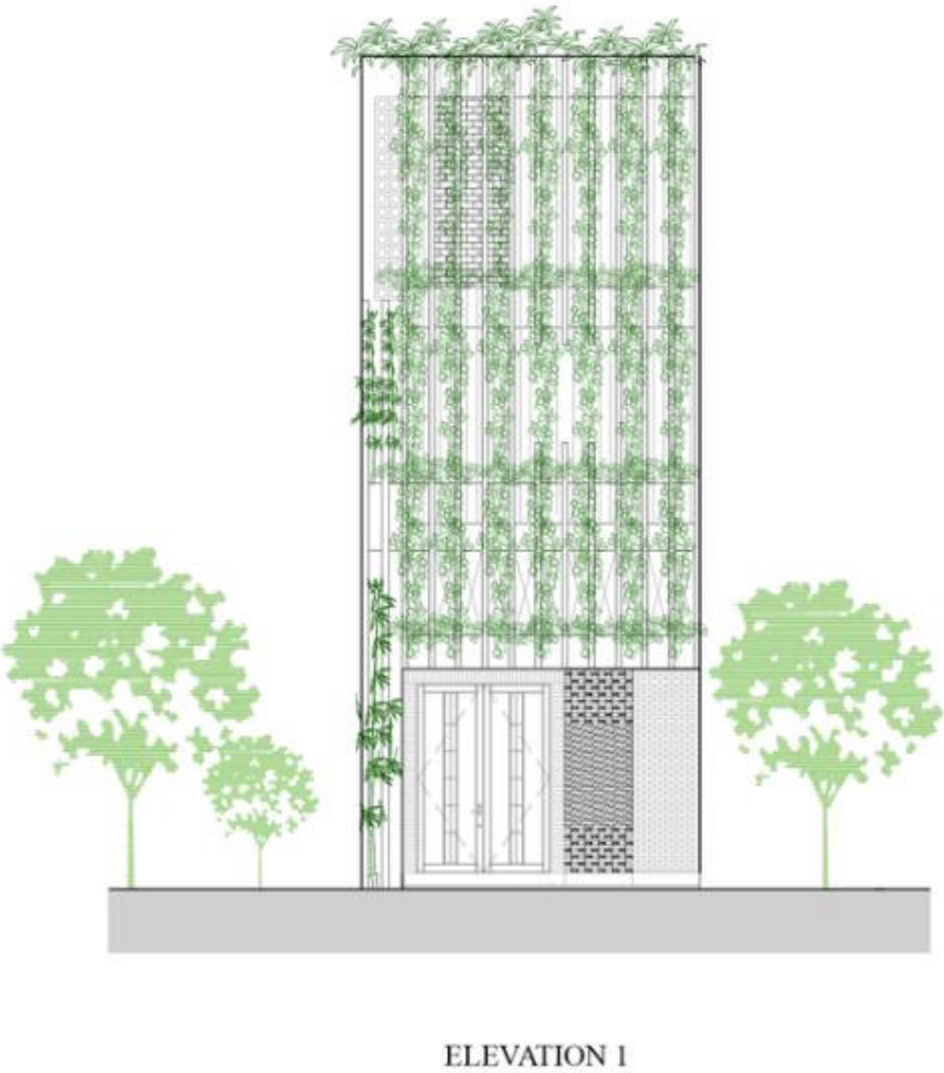


Figure 41. Southeast elevation of the Alpes building

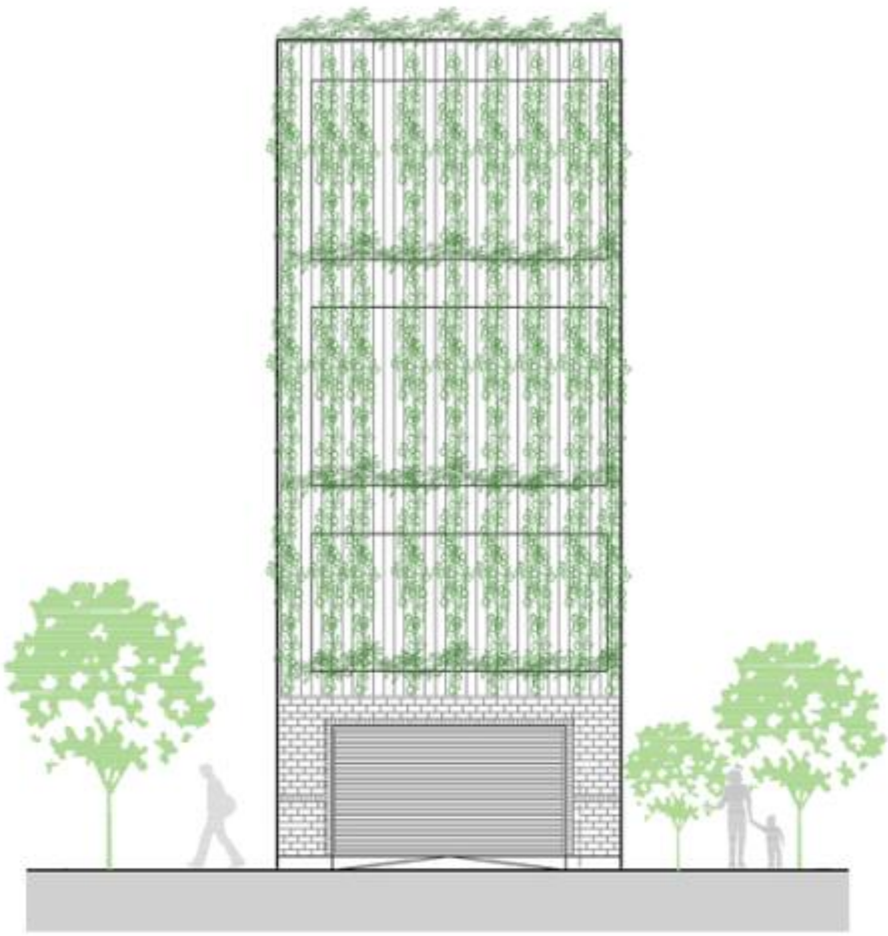


Figure 42. Northwest elevation of the Alpes building

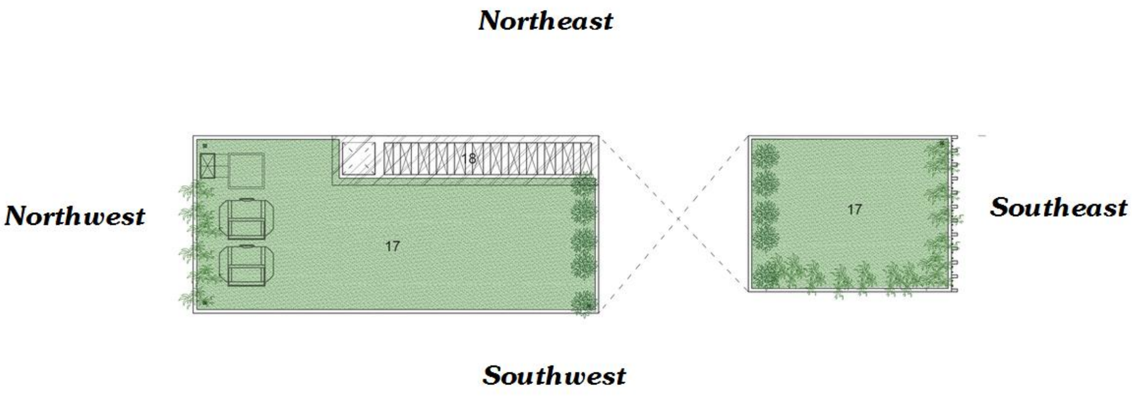


Figure 43. Building orientation of the Alpes building

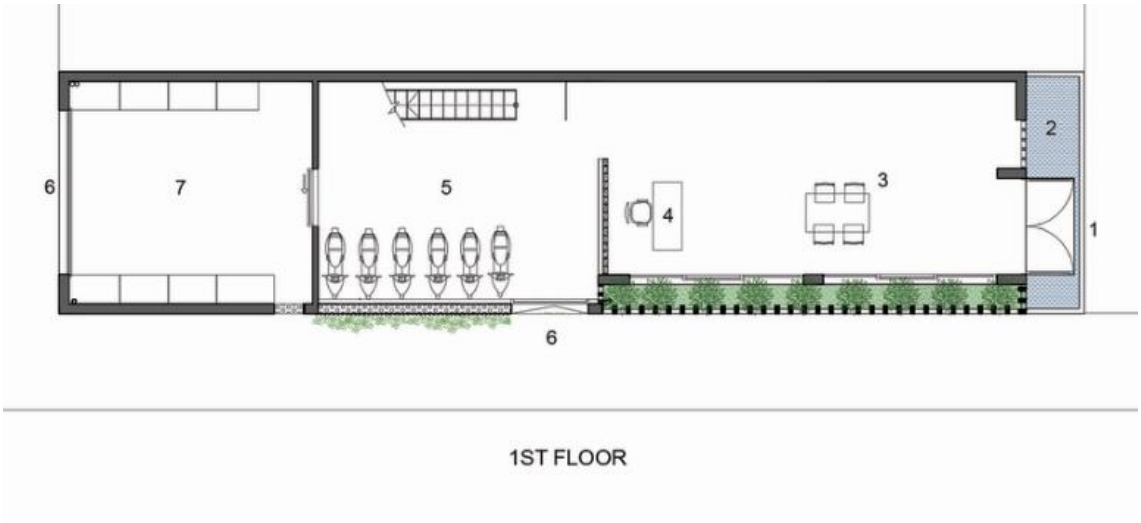


Figure 44. First floor of the Alpes building

Figure 45. Second floor of the Alpes building

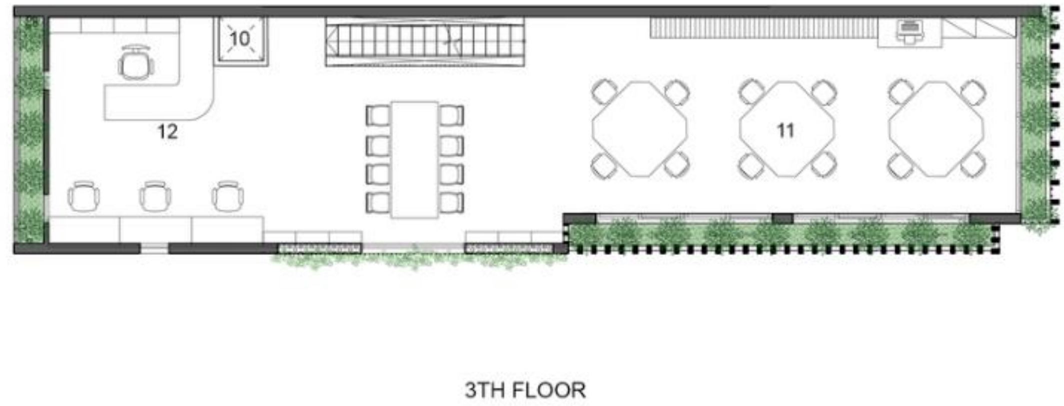


Figure 46. Third floor of the Alpes building

Figure 47. Fourth floor of the Alpes building

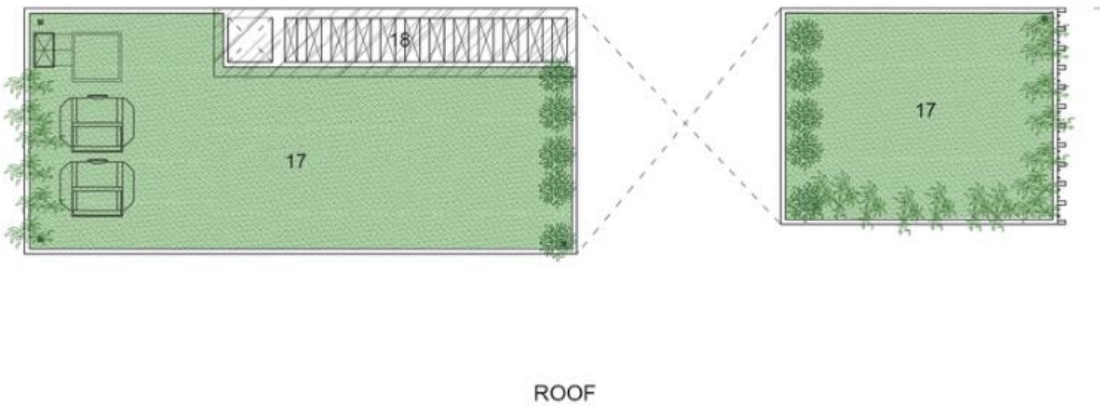


Figure 48. Roof of the Alpes building

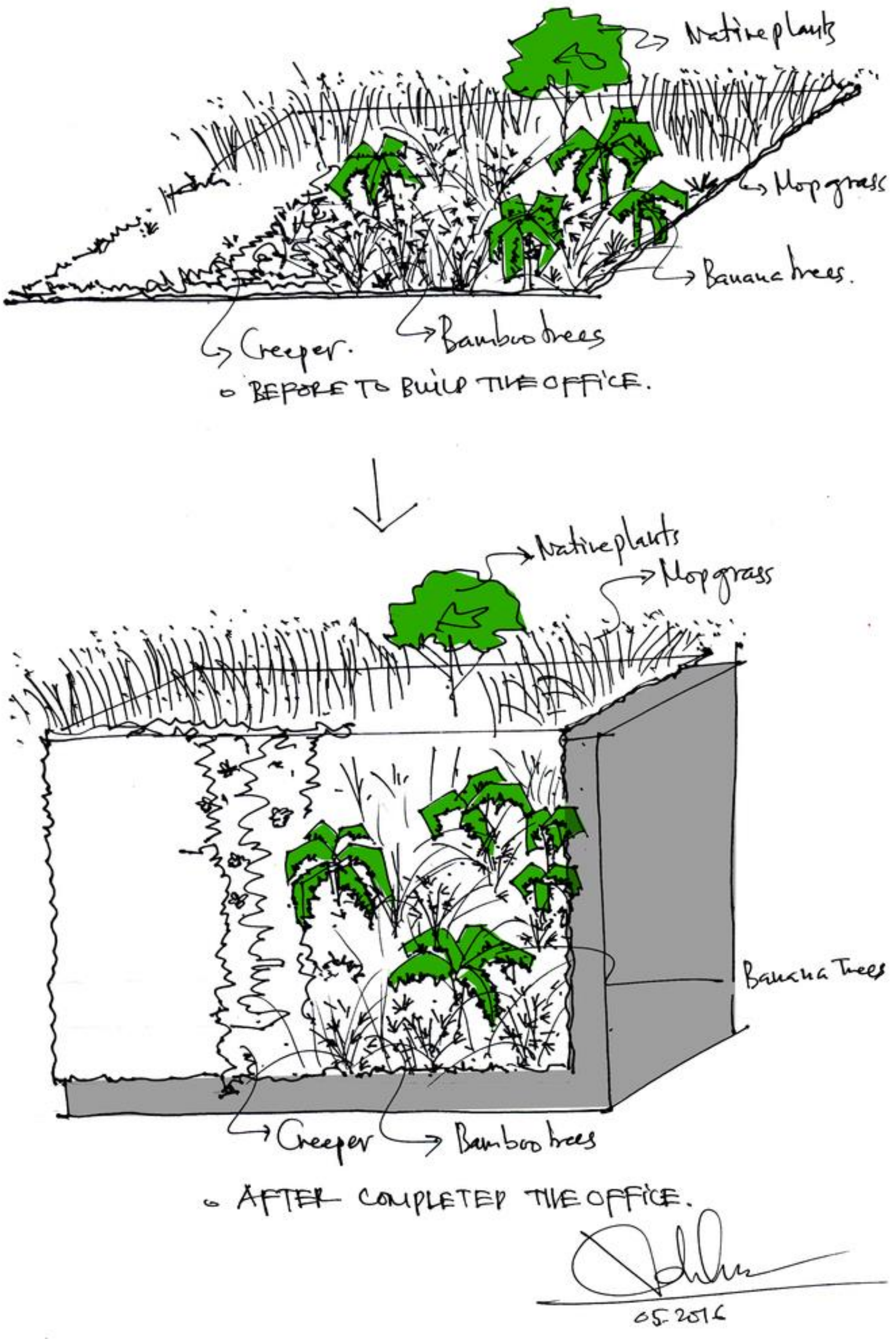


Figure 49. Combination of green space and building structures of the Alpes building

Appendix 3. LOTUS green building certification

Figure 50. Automatic irrigation system of the Alpes building

Figure 51. Drinking water

Figure 52. Kangaroo water purifier KG109 KNT

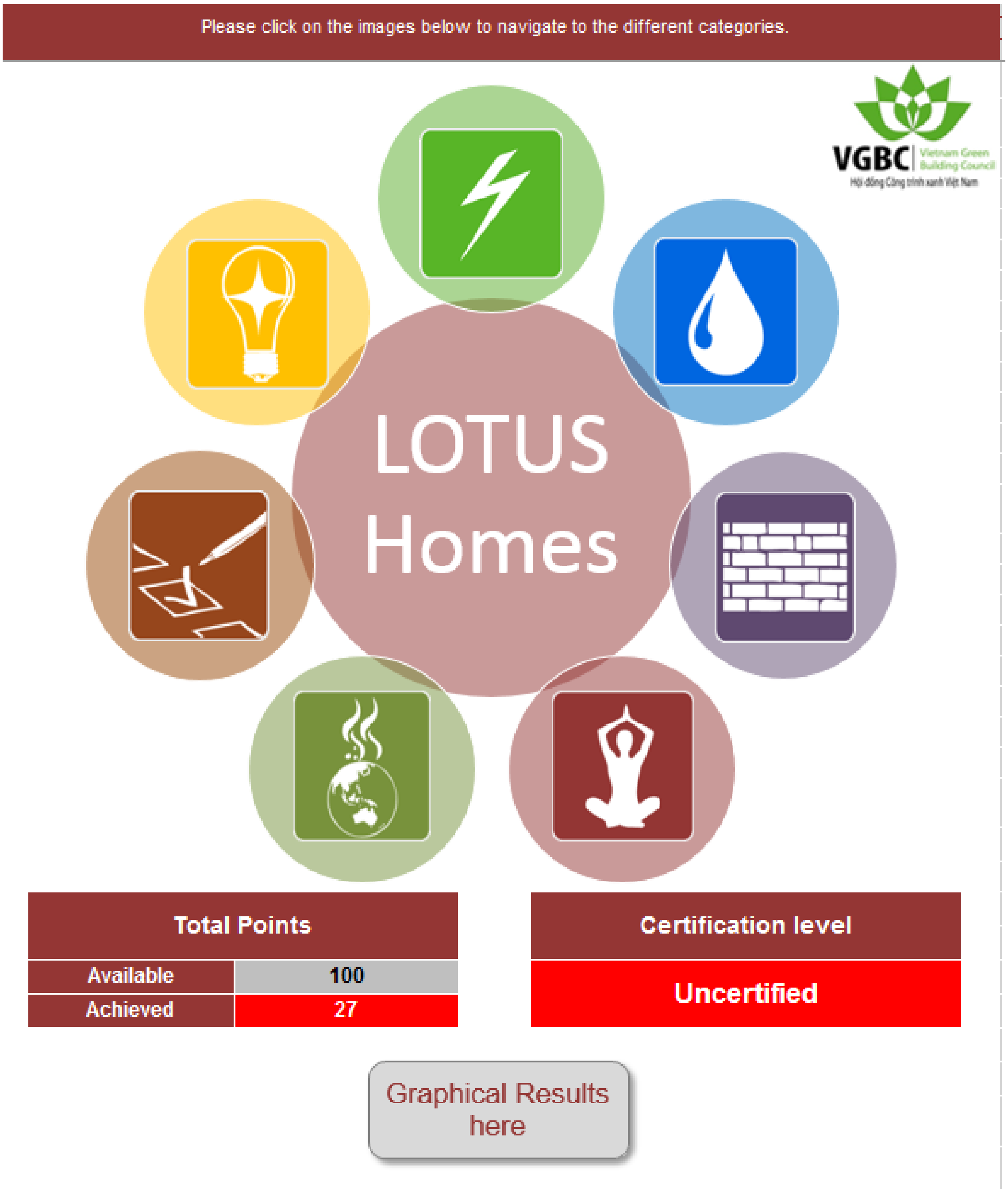


Figure 53. LOTUS Homes V1 System

LOTUS Homes V1 Scorecard

Energy		Possible points	Points
E-1	Passive Design	**5**	5
E-2	Building Envelope	**4**	1
E-3	Home Cooling	**6**	6
E-4	Artificial Lighting	**3**	0
E-5	Water Heating	**2**	0
E-6	Energy Efficient Appliances	**3**	0
E-7	Energy Monitors	**1**	0
BPC	Best Practice Credits	**5**	0
	Total	**29**	12

Water		Possible points	Points
W-1	Water Efficient Fixtures	**5**	0
W-2	Water Efficient Landscaping	**2**	2
W-3	Drinking Water	**1**	1
BPC	Best Practice Credits	**4**	0
	Total	**12**	3

Materials		Possible points	Points
M-1	Building Structure Materials	**3**	0
M-2	Non-structural Walls	**3**	0
M-3	Windows and Doors	**2**	2
M-4	Flooring Materials	**2**	0
M-5	Roofing Materials	**2**	0
M-6	Furniture	**2**	0
	Total	**14**	2

Innovation		Possible points	Points
Inn-1	Exceptional Performance Enhancement	**4**	0
Inn-2	Innovative Techniques / Initiatives		0
	Total	**4**	0

Figure 54. LOTUS Homes V1 Scorecard for the Alpes building

Local Environment		Possible points	Points
LE-1	Site Selection	**5**	2
LE-2	Site Design	**2**	2
LE-3	Vegetation	**2**	2
LE-4	Heat Island Effect	**2**	0
LE-5	Stormwater Runoff	**2**	0
LE-6	Flood Risk Mitigation	**1**	0
LE-7	Refrigerants	**1**	0
LE-8	Waste Management	**1**	0
BPC	Best Practice Credits	**1**	0
	Total	**17**	6

Health & Comfort		Possible points	Points
H-1	Fresh Air Supply	**2**	2
H-2	Ventilation in wet areas	**1**	0
H-3	Low-VOC Emissions	**4**	0
H-4	Daylighting	**3**	0
H-5	Acoustic Comfort	**1**	0
BPC	Best Practice Credits	**3**	0
	Total	**14**	2

Community & Management		Possible points	Points
CM-1	Design Management	**1**	0
CM-2	Construction Management	**5**	1
CM-3	Operational Management	**1**	1
BPC	Best Practice Credits	**3**	0
	Total	**10**	2

Figure 55. LOTUS Homes V1 Scorecard for the Alpes building

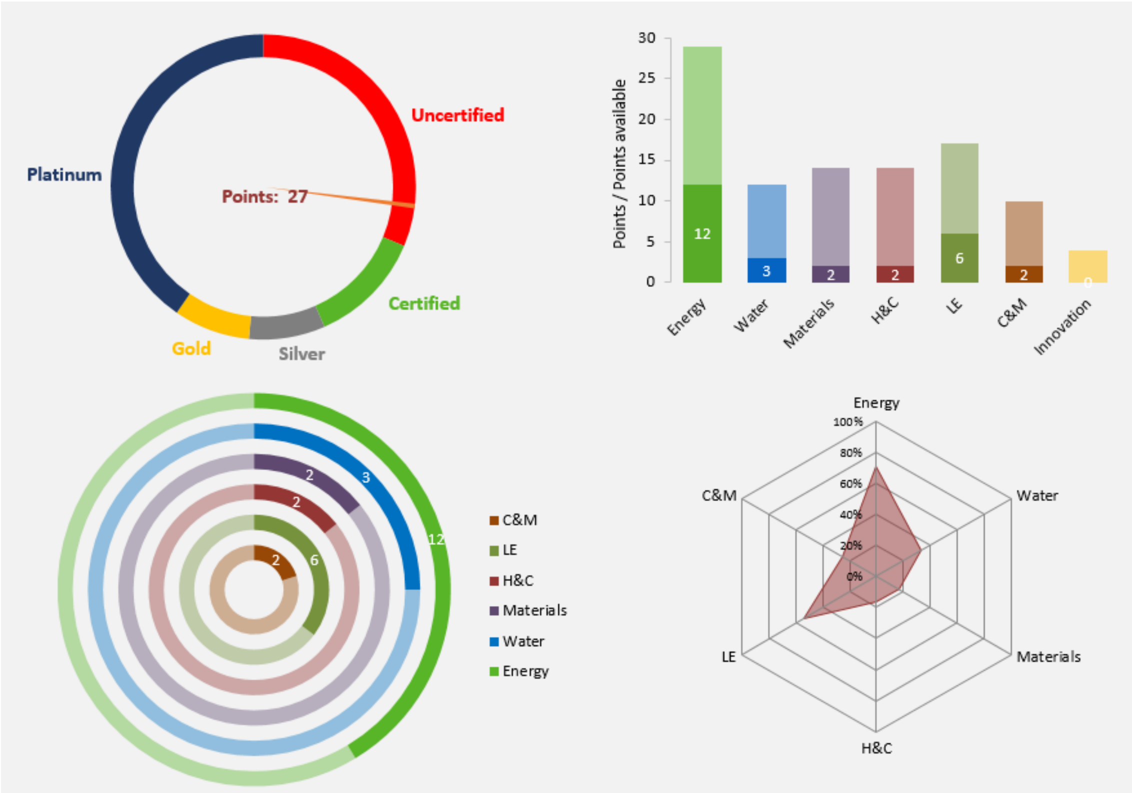


Figure 56. LOTUS Homes V1 Graphic result

Energy

To monitor and reduce the energy consumption of a building through, for example, passive design, the use of natural ventilation and the installation of energy-efficient equipment (HVAC, lighting, water heater, etc.)

See the Scorecard

Credit	Available points	Points
E-1 Passive Design	5	5
E-2 Building Envelope	4	1
E-3 Home Cooling	6	6
E-4 Artificial Lighting	3	0
E-5 Water Heating	2	0
E-6 Energy Efficient Appliances	3	0
E-7 Energy Monitor	1	0
Best Practice Credits	5	0
Total	**29**	**12**

Figure 57. LOTUS assessment system results of the Energy category for the Alpes building

Water

To reduce the water consumption of a building through the use of water-efficient fixtures, rainwater harvesting, gray water recycling and associated measures and to ensure a more sustainable management of the effluents

See the Scorecard

Credit	Available points	Points
W-1 Water Efficient Fixtures	5	0
W-2 Water Efficient Landscaping	2	2
W-3 Drinking Water	1	1
Best Practice Credits	4	0
Total	**12**	**3**

Figure 58. LOTUS assessment system results of the Water category for the Alpes building

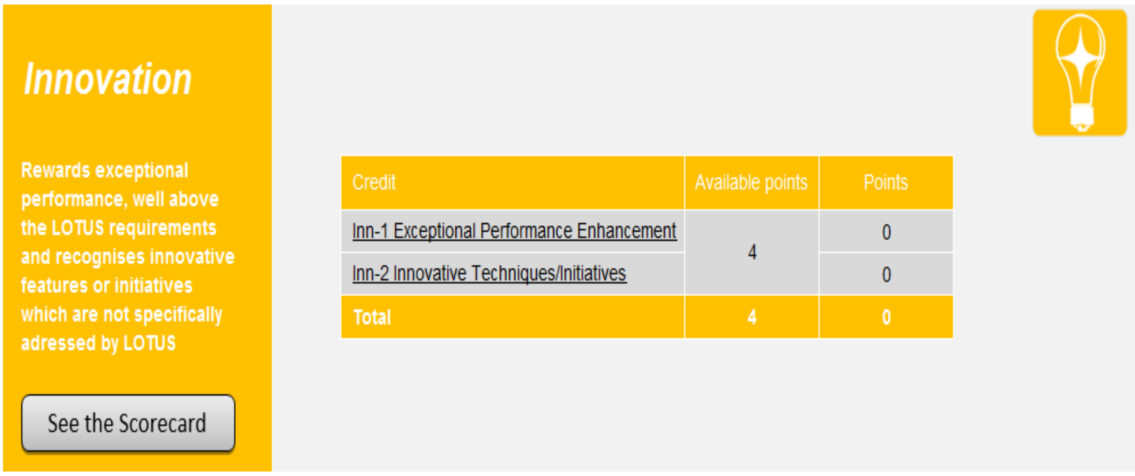
Materials

To encourage use of sustainable materials and reduce use of high-embodied-energy materials, for example trough the use of re-used and/or recycled materials.

See the Scorecard

Credit	Available points	Points
M-1 Building Structure Materials	3	0
M-2 Non-structural Walls	3	0
M-3 Windows and Doors	2	2
M-4 Flooring Materials	2	0
M-5 Roofing Materials	2	0
M-6 Furniture	2	0
Total	**14**	**2**

Figure 59. LOTUS assessment system results of the Materials category for the Alpes building



Innovation

Rewards exceptional performance, well above the LOTUS requirements and recognises innovative features or initiatives which are not specifically adressed by LOTUS

See the Scorecard

Credit	Available points	Points
Inn-1 Exceptional Performance Enhancement	4	0
Inn-2 Innovative Techniques/Initiatives		0
Total	**4**	**0**

Figure 60. LOTUS assessment system results of the Innovation category for the Alpes building

Local Environment

To protect the ecology of the site of the building and surrounding area, to encourage recycling practices, and to integrate adaptation and mitigation strategies.

See the Scorecard

Credit	Available points	Points
LE-1 Site Selection	5	2
LE-2 Site Design	2	2
LE-3 Vegetation	2	2
LE-4 Heat Island Effect	2	0
LE-5 Storm Water Runoff	2	0
LE-6 Flood Risk Mitigation	1	0
LE-7 Refrigerants	1	0
LE-8 Waste Management	1	0
LE-BPC-1 Composting	1	0
Total	**17**	**6**

Figure 61. LOTUS assessment system results of the Local Environment category for the Alpes building

Health & Comfort

To ensure high indoor environmental quality, through the optimisation of indoor air quality, daylighting, and thermal comfort.

See the Scorecard

Credit	Available points	Points
H-1 Fresh Air Supply	2	2
H-2 Ventilation in Wet Areas	1	0
H-3 Low-VOC Emissions Products	4	0
H-4 Daylighting	3	0
H-5 Acoustic Comfort	1	0
Best Practice Credits	3	0
Total	**14**	**2**

Figure 62. LOTUS assessment system results of the Health & Comfort category for the Alpes building

Community & Management

To increase the awareness of how buildings affect the community and to ensure that, throughout the project, all targets set up are competently and effectively managed.

See the Scorecard

Credit	Available points	Points
CM-1 Design Stage	1	0
CM-2 Construction Management	5	1
CM-3 Operational Management	1	1
Best Practice Credits	3	0
Total	**10**	**2**

Figure 63. LOTUS assessment system results of the Community & Management category for the Alpes building

Appendix 4. Photovoltaic system

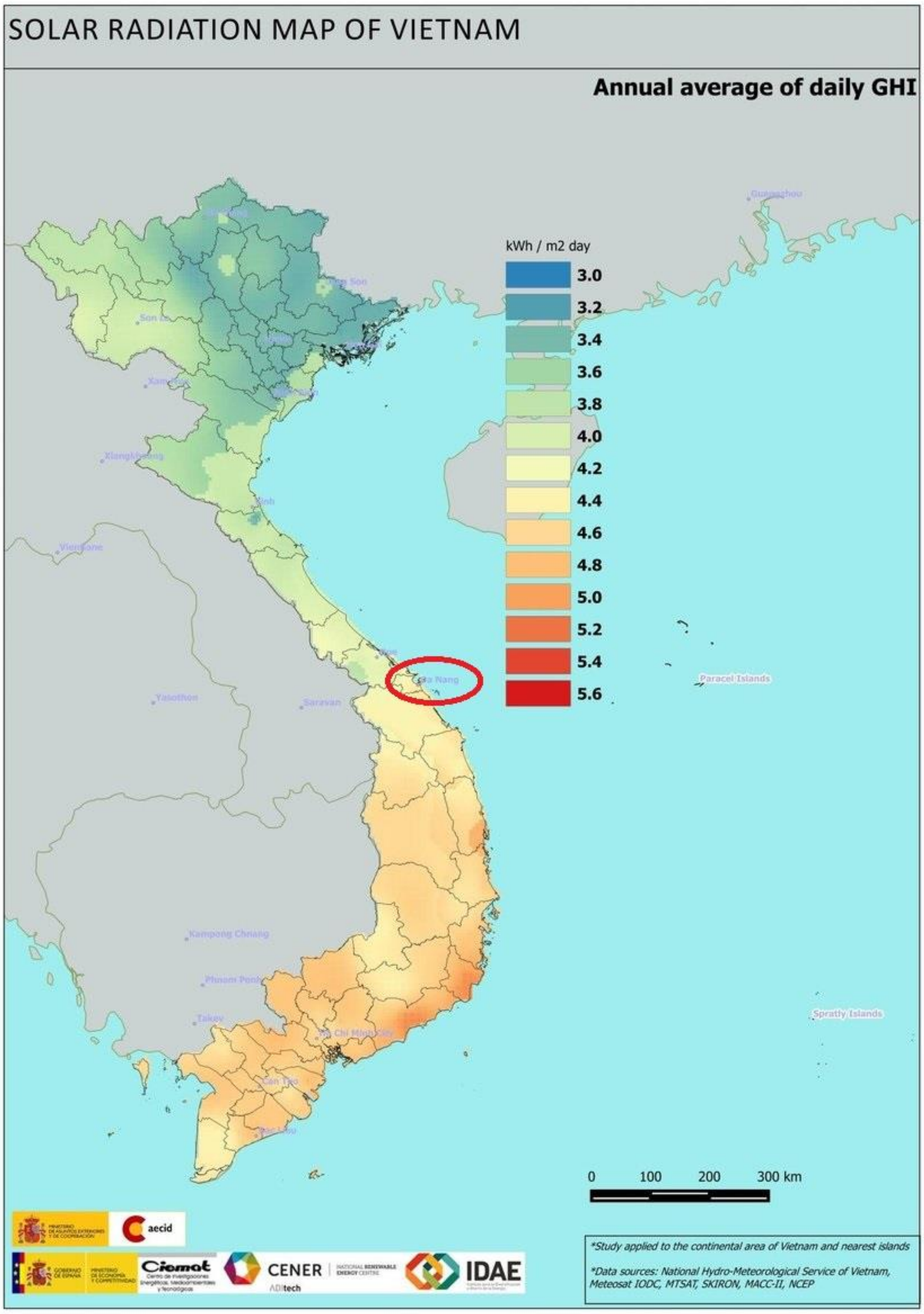


Figure 64. Solar radiation map of Vietnam

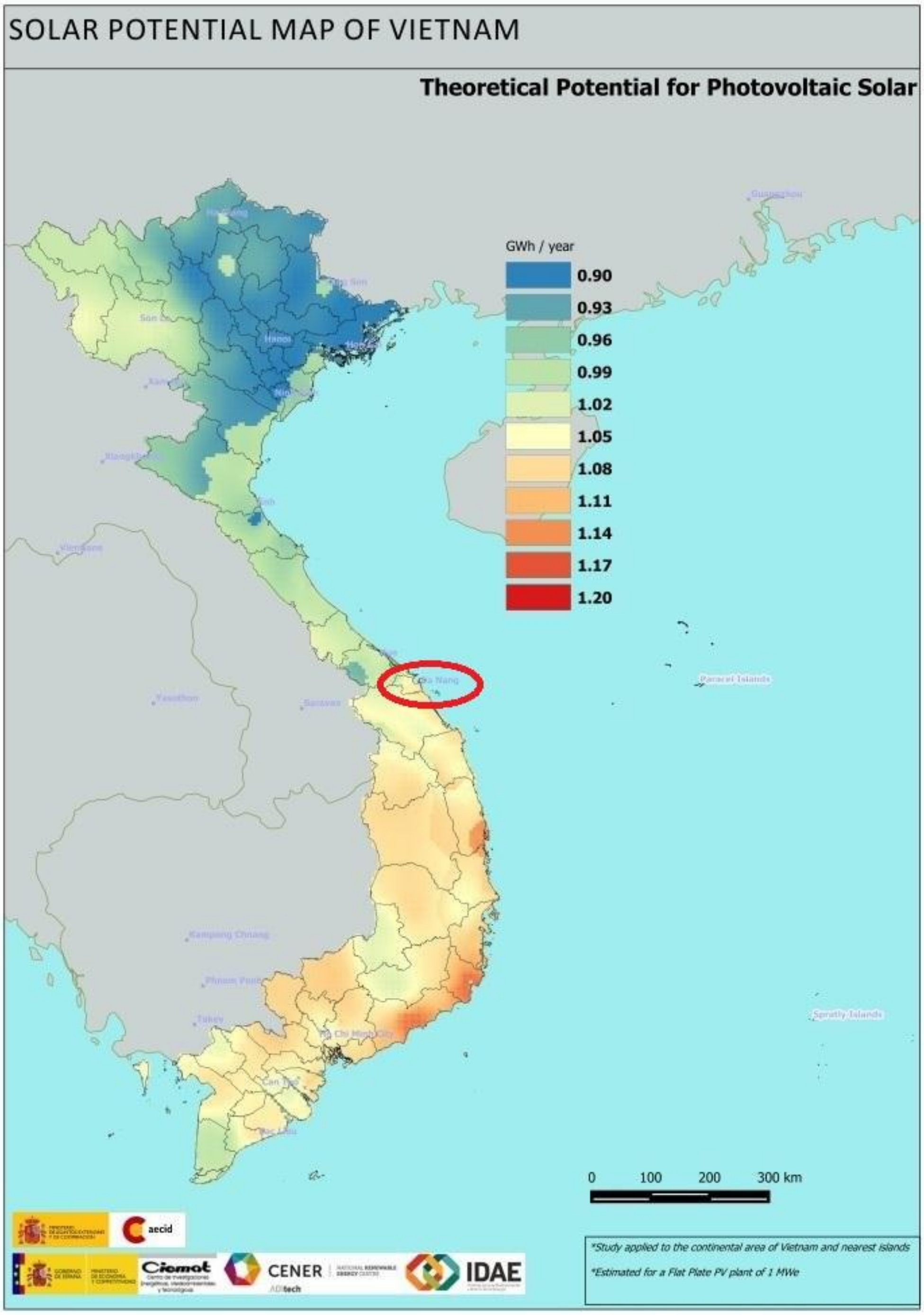


Figure 65. Solar potential map of Vietnam

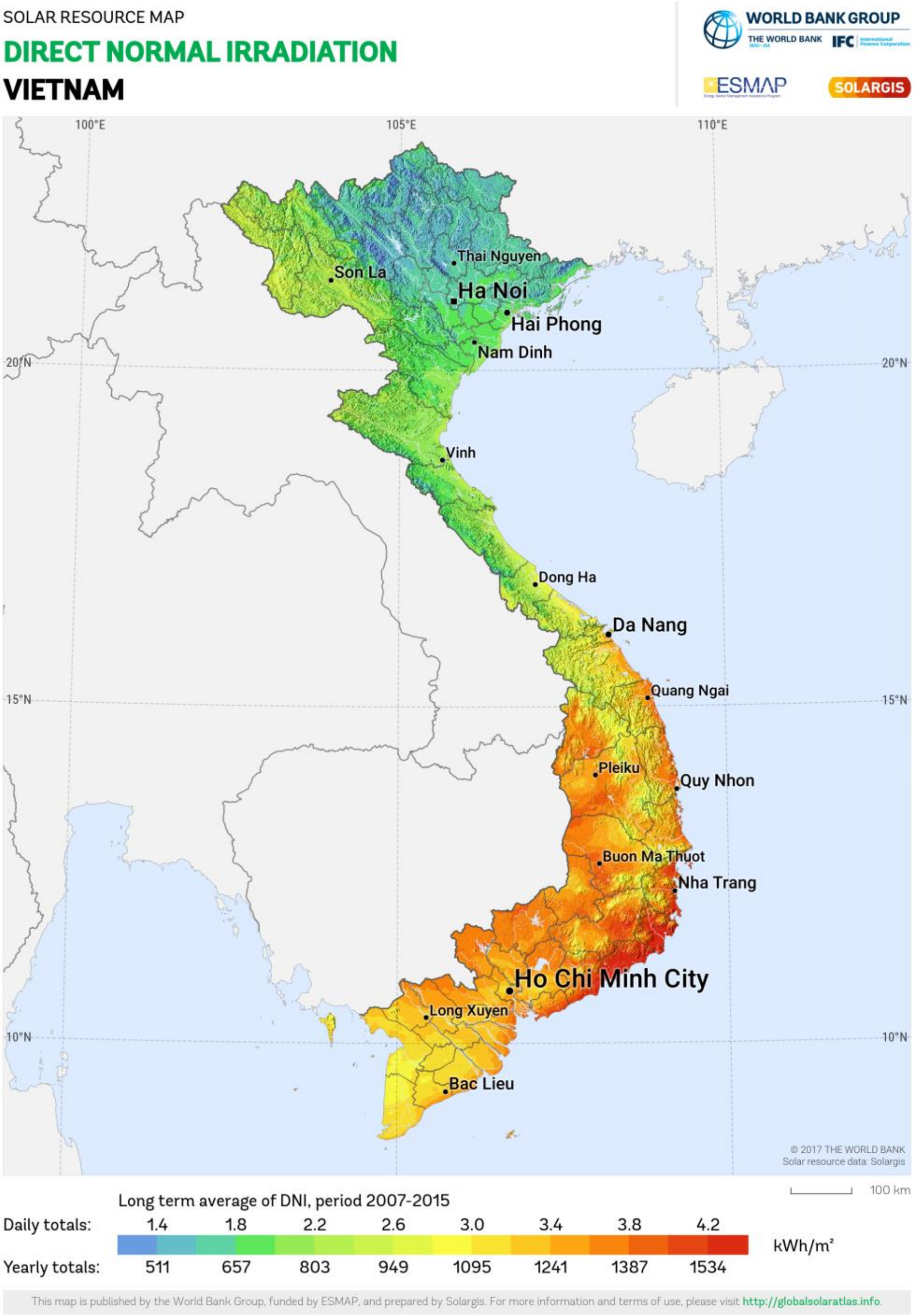


Figure 66. Direct normal irradiation of Vietnam

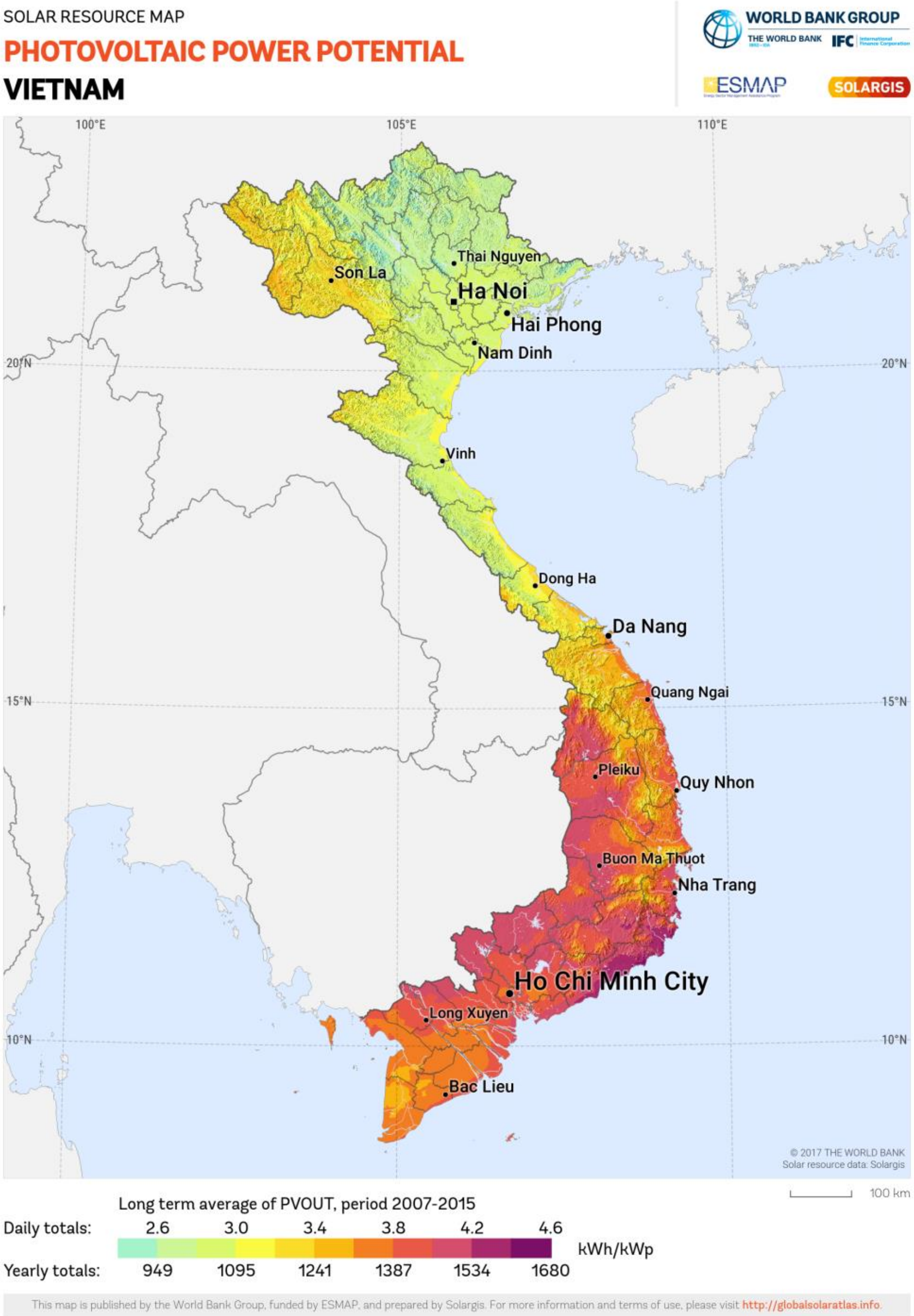


Figure 67. Photovoltaic power potential of Vietna

Payback time graph

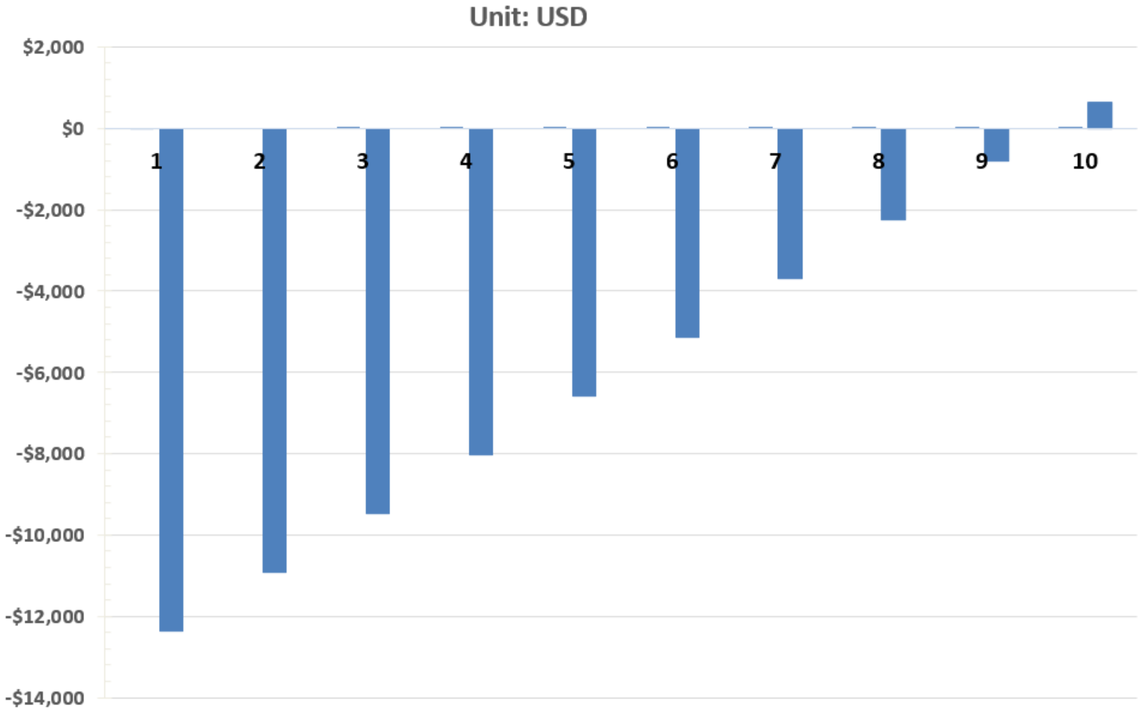


Figure 68. Payback time of the solar panels system for the Alpes building