Study on energy efficiency in Vietnamese row house - case study of Tang Nhon Phu A Ward, District 9, HCMC

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Abstract: District 9 is a new urban development area which is well-known as an industrial city in the rear of Ho Chi Minh City. This area has special characteristics which are different from central downtown. The housing of district 9 is a new urban area so that it is easier to orient particular architectural style accordance with climatic conditions and other conditions. However, at present, these new residential areas are rising with no clear management of architectural form. That is the reason lead to shortcomings such as: increasing the use of electricity, affecting to climate change and creating urban heat island, increasing costs of energy use. Those problems will be difficult to overcome in the future if we don't have the right attention on it.

By using a combination of multiple methods such as: data collection, case study analysis method, GIS, research by design, etc., this research topic will pay attention on analysis the row house in Tang Nhon Phu A Ward of district 9 and trying to propose some solution and management criteria to local government. The analysis results will ensure that the conclusions reflect the realities of the situation, those also become the basis for the proposed solutions to deal with the existence problems. The result of research may become an application research platform for the related research topics.

1. Introduction

Utilizing energy savings has always been the interesting topics for many scientists around the world especially in the context of climate change. [1]

In the welded and temperate countries, the model of Passive House was introduced in the 1990s under the management of Passive House Institute, Germany. Accordingly, a passive house must achieve a minimum heating energy consumption of 15kwh/m2. This theory becomes more and more popular. More than 25000 Passive House have been built around the world [2].

An example in European country is the Swedish Passive House. This building was built followed the Passive House Standard to reduce the using of energy (approximately 65-75%) [3].

In tropical countries, There are so many solutions to cost down the energy consumption such as creating a fresh micro environment by using the insulation material, using energy saving equipment, etc. [4]. The example of China, the solutions are replacing ordinary material with insulating material, using double-glazed windows, proposing the solutions for functional space suitable with the physical

condition of the research site. This model is being widely used to promote energy saving in this country [5].

There are a lot of studies on energy saving on over the world. However, there are different climatic characteristics and citizen habits in different locations. So, further research is needed to meet the needs of differentiated areas.

In Vietnam, the traditional housing is considered to be in harmony with nature and people. Under the influence of global climate change and rapid urbanization, the urban housing have not yet ensured the comfort of the weather conditions.[6]. More than that, The ineffective use of household appliances plays a non-trivial role that affects installation, frequency of consumption, and energy savings [7]. Energy-saving housing models are almost unattended. A part of the architects in Vietnam began to notice the problem of the architecture but also limited in terms of research. Most of the solutions are only concerned with the development of external forms, compromise with microclimate by technology-based solutions, or have not been able to address practical problems. The principal findings of the study are in the concept of green architecture, but there are no specific solutions in the design but only in the general theory or in the exploration of energy efficient solutions (LED).[8]
For those reasons, the targets of research topics are to propose the changing of micro-climate by giving the suitable architectural design solutions. Moreover, the row house owner's behavior is also considered in this study.

This research topic will pay attention on analysis the Tang Nhon Phu A Ward of district 9 and trying to propose some solution and management criteria to local government. The result of research may become an application research platform for the related research topics. By applying GIS to the analysis of microclimatic data and visualization of results, it will become a positive support method for architects presenting their solutions and evaluating the results. This study is limited to one variable in temperature; other variables such as humidity, light intensity, etc. will be introduced in the next section.
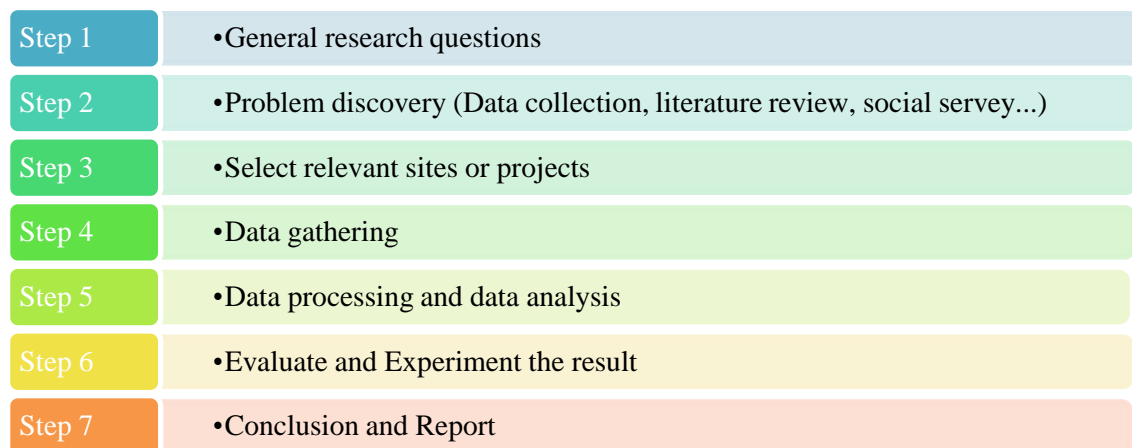
2. Methodology

District 9 is a new urban development area which is well-known as an industrial city in the rear of Ho Chi Minh City. This area has special characteristics which are different from central areas of Ho Chi Minh City. The housing of district 9 is a new urban area so that it is easier to orient particular architectural style accordance with climatic conditions and other conditions. However, at present, these new residential areas are rising with no clear management of architectural form. That is the reason lead to shortcomings such as: increasing the use of electricity, affecting to climate change and creating urban heat island, increasing costs of energy use. Those problems will be difficult to overcome in the future if we do not have the right attention on it.

This study is planning to get the data from a set of research methods such as: data collection[9], case study analysis method [10,11], GIS[12,13], research by design, etc.

The data collection method will provide the primary data and secondary data from multiple sources. After that, case study analysis method will support the researcher a tool to make the analysis of the research area. Moreover, a set of ArcGIS's toolboxes also was applied to analyses the physical condition of row house in District 9, HCMC. The proposed solutions will apply on a real row house in the site to re-evaluate the effectiveness of the research results (research by design methods).

Through these methods, supportive research data will be collected, suggesting appropriate solutions through the research process below:

Step 1	•General research questions
Step 2	•Problem discovery (Data collection, literature review, social servey...)
Step 3	•Select relevant sites or projects
Step 4	•Data gathering
Step 5	•Data processing and data analysis
Step 6	•Evaluate and Experiment the result
Step 7	•Conclusion and Report

Figure 1. The research process

By using a combination of multiple methods, the analysis results will ensure that the conclusions reflect the realities of the situation that is the basis for the solutions proposed in the following sections.

3. Research results

3.1. Overview

As followed the information of HCMC Statistics Department in 2010, District 9 is about 7 km far from the city center along the Xa Lo Ha Noi Highway. There are 13 wards with an area of 114 km^2, population of 263,486 people, density of 2,311 people / km^2. Despite being urbanized since 1997, residents in District 9 are still relatively low in comparison with newly established districts such as Binh Tan District, Tan Phu District[14]. Hi-tech Park of Ho Chi Minh City located in district 9 has been built and put into operation. The new residential area of district 9 was formed under the positive influence of High Tech Park such as: Singa City, TDL Residence, HTReal 898, Tang Long River View, Valencia Riverside, Viet Nhan Villa Residence, Nam Khang Residence, Thai Duong Luxury, etc. Though, District 9 is the largest and least populated district in comparison with the rest of Ho Chi Minh City at present, this area is forecasted to grow very fast in the future with the development dynamics of local industrial zone and the synchronous technical infrastructure system.

Tang Nhon Phu A Ward (population: 23.158 people, area: 418.98 ha) is one of center ward of district 9, located near Hiep Phu Ward. Over the years with the impact of the market mechanism, the rapid increasing of industrial, service projects and the development of residential areas of Tang Nhon Phu A Ward has resulted in a lot of difficulties in the management of the land. Moreover, it also has a great impact on the social life of local residents.

Figure 2. Location of Tang Nhon Phu A Ward in Google map
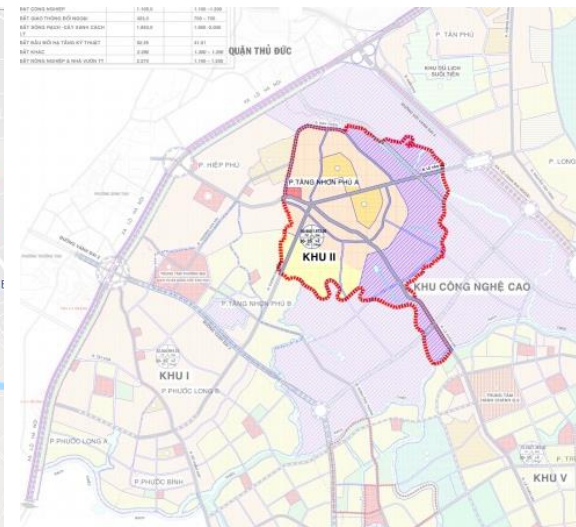
Figure 3. Location of Tang Nhon Phu A Ward in District 9's Master Plan from People's Committee of Tang Nhon Phu A Ward, District 9, 2017

Local climatic conditions have a great impact on each project as well as the design solution. According to general information about Ho Chi Minh City, the common characteristics of Ho Chi Minh City climate are high temperature (lowest average temperature is 25.7°C on the middle of December and January, the absolute high temperature is 38.6°C on April).

There are two seasons in Ho Chi Minh City. Rainy season begin from May to November, dry season begin from December to April next year. The rainfall is high, average 1.949 mm / year. The highest rainfall is 2,718 mm (1908) and the smallest rainfall was 1,392 mm (1958). The average number of rainy days is 159 days. Approximately 90% of annual rainfall is concentrated from May to November; June and September usually have the highest rainfall. Almost the north districts often have higher rainfall than the southern and southwestern districts.

The amount of radiation is plentiful, about 140 Kcal / cm2 / year. An average hour of sunshine / month is about 160-270 hours. The average air temperature is 27°C.

Relative humidity of air is 79.5% per year; average rainy season is 80% and absolute high values up to 100%; Average dry season is 74.5% and absolute low down to 20%.

Ho Chi Minh City is affected by two main wind directions and mainly monsoon winds in the West - Southwest and North - Northeast. The Western-Southwest winds from the Indian Ocean blew in the rainy season, from June to October, with an average speed of 3.6 m/s and the strongest winds in August, averaging 4.5 m/s. The North-East wind blows from the East Sea during the dry season, from November to February, with an average speed of 2.4 m/s. In addition, there is south - southeast wind, from March to May average speed of 3.7 m/s.

Due to extreme weather conditions, especially in terms of temperature and humidity in HCMC, housing projects need to be specially designed to reduce the use of artificial energy, creating comfortable for the people using the building.
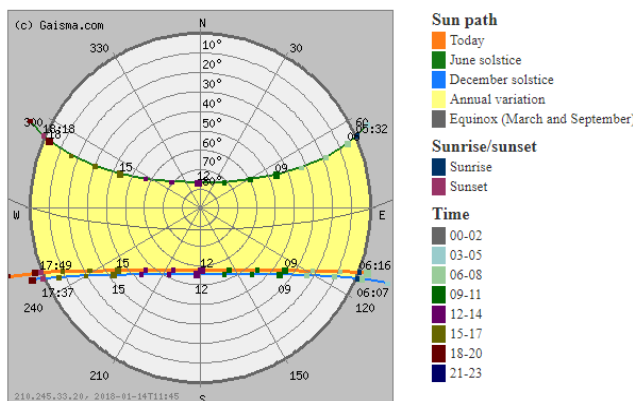
Figure 4. Ho Chi Minh City - Sun path diagram of Gaisma.com, 10/01/2018
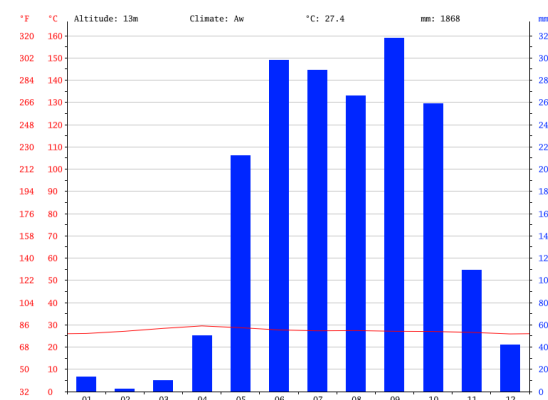
Figure 5. Climograph of Ho Chi Minh City from en.climate-data.org, 10/01/2018

Tang Nhon Phu A Ward has about 4,309 households, divided into 4 main types of home including: villas, apartment building, row houses, garden houses which are interspersed throughout the region. In the types of housing which was listed above, the type of row house occupied the majority (46.3%) of the dwellings in the area. In addition, the row house (also known as the townhouse, pipe house) has many limitations such as construction conditions, small area, etc. while the type of garden house and villas have the advantage of wide area of and easy to handle the architecture style or dealing with micro climate. This type of row house actually poses challenges for architects to create a design that assures efficiency in natural climate conditioning for energy savings.


Noted:
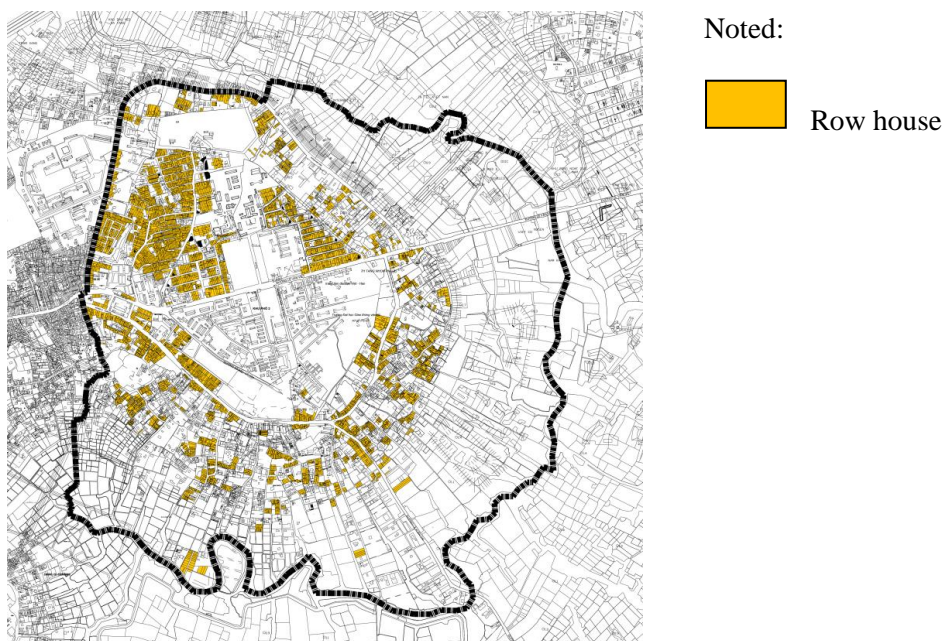
Row house

Figure 6. The existing row houses distribution in Tang Nhon Phu A Ward, District 9

Because of those reason, the research topic pay attention on the type of row house to give the suitable solution which may help improving the living quality and reduce the use of energy.

3.2. Case study analysis

There are two kinds of row house: one facade and two facade row house. The two-facade row house is

usually stayed in the corner of each block. The amount of two- facade row house is less than the one-facade row house. The research team selected the sample for analysis. Sampling criteria should be the most commonly designed with local street-house designs. More than that, typical samples represent the type of one- facade row house and two-facade row house to carry out for analysis (see Figure below).
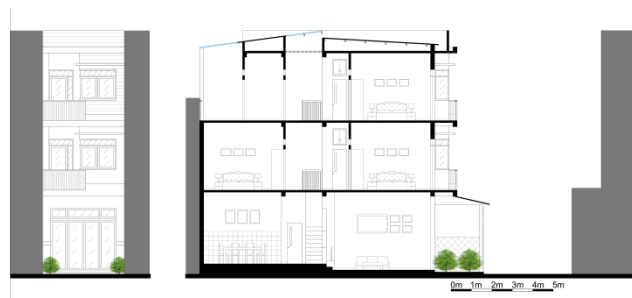
Figure 7. Sample of one-facade row house at No. 35, 449 Street, Tang Nhon Phu A, District 9, HCMC.

Figure 8. Sample of two-facade row house at No. 24, 447 Street, Tang Nhon Phu A, District 9, HCMC.

Each type of house has different advantages and needs to be considered separately, as shown in the table below:

Table 1. The type of row house comparison

Housing type	Strength	Weakness
One-facade row house	- On the side of the house is the neighbor's house, reducing the heat-resistant surface directly from the sun => lower indoor temperature	- No side windows => poor ventilation
		- Long house (~ 20-25m), only have 1 facade => the lack of natural light in the home if there are no suitable design solution

| Two-facade row house | - Easy to obtain natural light | - Larger surface area to receive direct light => increase indoor temperature |
| | - Easy to get wind and light from the windows on both sides of the house | - Higher construction costs |

The research team conducted a field survey and integrated the classification of row houses. After that, 2 typical row house samples are selected. Microclimate data and energy needs of households in Tang Nhon Phu A district were also collected and assessed by using appropriate tools.

Regarding the demand for energy, the research team used a random sampling method with 1% of total number of households in Tang Nhon Phu A Q9 ward (40 samples). The results of the survey show that 45.7% of the people are satisfied and above the level of satisfaction with their current home, 54.3% are not satisfied. The main cause of unsatisfied is high indoor temperature, small size of house and no ventilation.

The average household electricity price survey shows that monthly electricity bills range from 250,000VND to 750,000VND and up to more than 2 million VND. According to the landlord, electrical equipment caused most power consuming are: air conditioning, refrigerator, lighting equipment, washing machine, TV.

In addition, when asked about the criteria for the use of micro-climate control appliances including air conditioning and lighting equipment, the user said that they would start using the air conditioners when the room temperature approach 30°C. The temperature when using the air conditioner is at 19-26°C. The regular time frames at 10:30 - 14:00 or 19:00 - 22:00, full day use for mix-use row house. For lighting equipment, most people say they often go to work during the day so electrical equipment are used a lot at night. For household or home-based businesses, most homes lack natural light, and bulbs operate nearly 20/24 hours per day.

The survey results show that local people still have not met the needs in an optimal way. Most of them have to use temporary remedies, using artificial equipment such as air conditioning and lighting equipment to meet the daily needs of the family. Data collection was conducted over a 1-year period. The data recorded is the data of temperature and illumination. These are two indicators directly affect the energy needs of the people. The article focuses on the analysis the temperature data (at the coolest and hottest month of year). Incorporation of data into analysis by using ArcGIS tool provides thermal interpolation diagram and the microclimate analysis diagram as follows:

3.2.1. One-facade row house
One-facade row house is often confined by neighbor buildings, so those building are unable to open the door for light and ventilation. There are many houses do not have enough length so they must to use the elevator space for creating air circulation. This also creates some of the effects on indoor microclimates
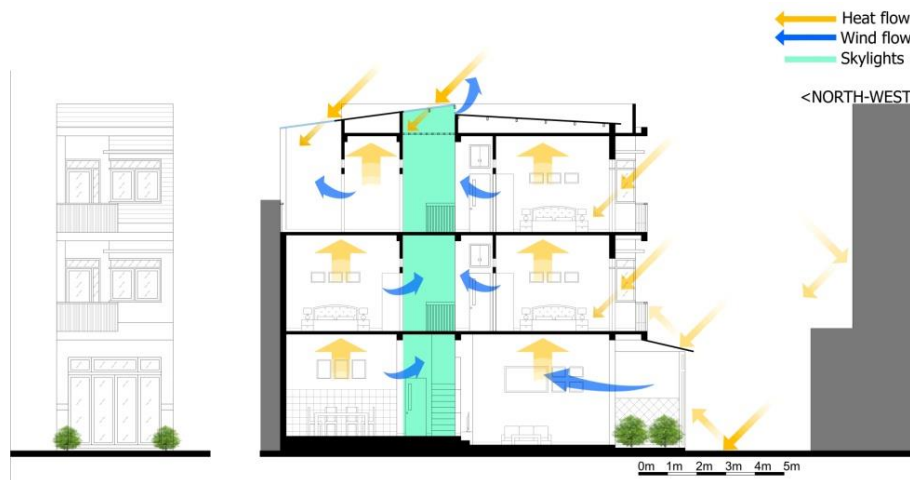
Figure 9. The one-facade microclimate analysis diagram

(Unit: ºC)

Figure 10. The one-facade thermal interpolation diagram on the coolest month of year
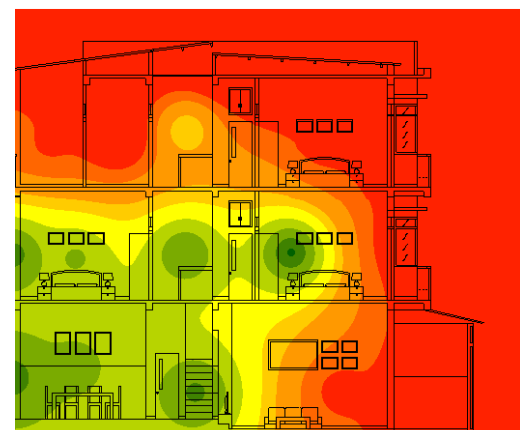
Figure 11. The one-facade thermal interpolation diagram on the hottest month of year

From the analysis results which were showed on the diagram above, we can easily find that:

- This project is short of length so it is not possible to build a vent through the floor, and poor circulation of air.
- No ventilation at the end of the house because of no window or back door
- The front bedroom is heavily impacted by sunlight while lacking in shielding.
- Indoor space is missing natural light.
- Looking at the heat spectrum on the thermal interpolation diagram, the temperature inside the room is almost under the influence of the sun. The fact that the building is surrounded by adjacent buildings, only the roof and facade is affected by the solar radiation.
- As the temperature of the outside air increases and the air circulation in the house decreases, the internal temperature also increases, the cool space in the house decreases dramatically.

In order to cool the interior space, the owners are usually equipped with air conditioning system, or fans ... These devices contribute to energy consumption and heat generation during the operation.

3.2.2. Two-facade row house

The two-storey row house type is usually built at the corner of the road, so there are many conditions to open windows for lightening and ventilation. Most of this type of house rarely was designed with skylight. The windows, balconies are usually arranged to get the natural light and release the air from inside to the outside.
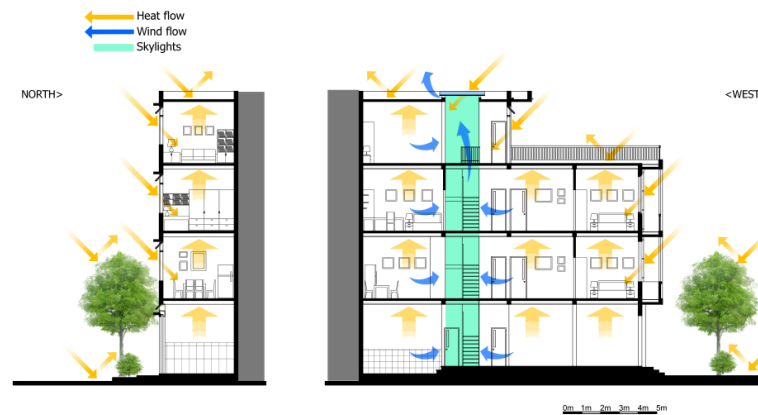
Figure 12. The two-facade microclimate analysis diagram

(Unit: ^{o}C)
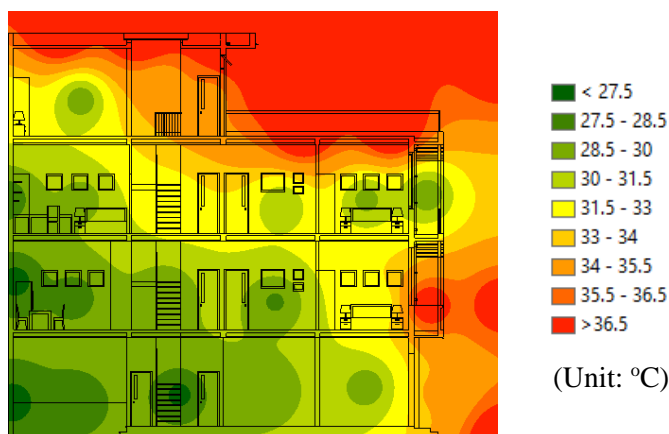
Figure 13. The two-facade thermal interpolation diagram on the coolest month of year
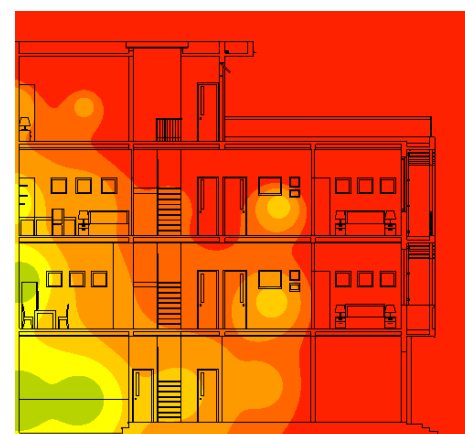
Figure 14. The two-facade thermal interpolation diagram on the hotest month of year

The analysis results of this case are:
- Because there are two facades exposed to the external environment, the building almost absorbed large amounts of radiation from the sun.
- The building is covered with a metal roof or a layer of reinforced concrete roof so that the sun affects directly to the roof, the terrace and indirectly affect the room inside.
- At sunrise, most of the interior space is heated. The inner temperature is always high (from 30-36oC)
- The windows are also affected by the sun, which increases the room temperature.

The two-facade buildings normally suffer more solar radiation than other types of facades, thus greatly increasing the room temperature. The traditional solution is to use a fan or air conditioning to reduce the heat.

3.3. The proposed solutions

In order to solve the thermal problems for the one and two-facades, the researcher proposes some solutions as follows:

- The one-facade row house:
- It is recommended to reserve a space behind the house for back yard or atriums (size may vary from 0.5 - 2m). Functional rooms inside the home should be designed in close contact with outside open space by windows or corridors. The roof is built in two layers (a layer of beneath concrete roof combined with one layer of tole roof above). The front surface should add a sunshade system to reduce exposure to the sun and to decorate.
- The one-facade row house:
- The building takes advantage of the two-facade building to get sunlight from both sides, but builds the side corridors, or balconies to minimize the heat. The roof is built in two layers (a layer of beneath concrete roof combined with one layer of tole roof above). Those layers have the appropriate distance to create an air cushion. The façade uses a system of sunshades, as well as a closed balcony structure. The staircase skylight is designed higher than usual with ventilation slots. The outer walls are constructed in three layers, consisting of two layers of bricks and one layers of air in the middle. The main doors and windows is designed high (2m high for window and 3m high for main door) with flaps for natural ventilation.

The above solutions are applicable to the same type of houses. The construction size is equivalent and the neighboring position. Those houses have the same direction and similar impact of the external environment.
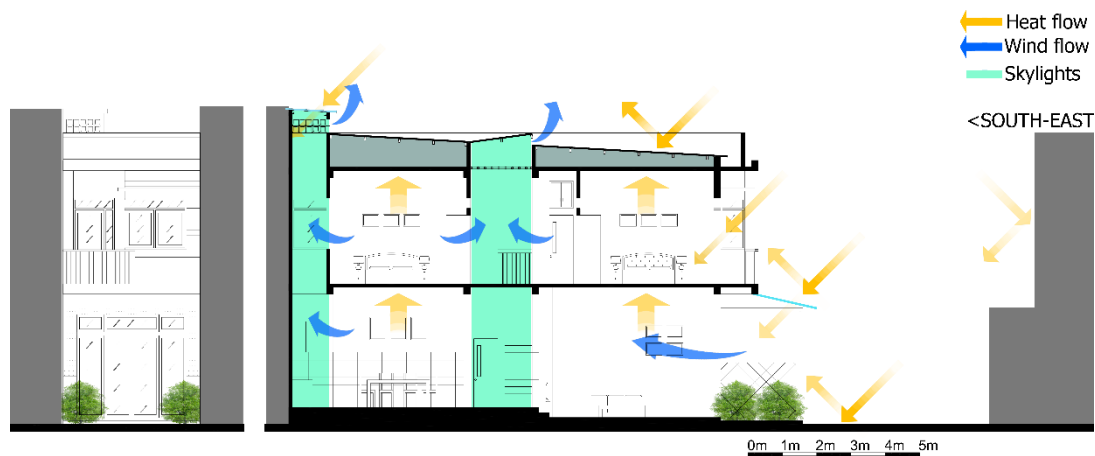

**Figure 15.** One - facade housing at No. C25/2, 449 street, Tang Nhon Phu A Ward, District 9, HCMC.

Figure 16. Two - facade housing at No. 74G, Lang Tang Phu street, Tang Nhon Phu A Ward, District 9, HCMC.

3.3.1. One-facade row house
This case study was built in internal road only 5m wide. The height of row houses is from 7m to 12m. The main road of the site is East - South. This house is designed with a small backyard and a skylight at the bottom of the staircase which is connect dining room with living room on the ground floor and 2 bedrooms on the 2nd floor.
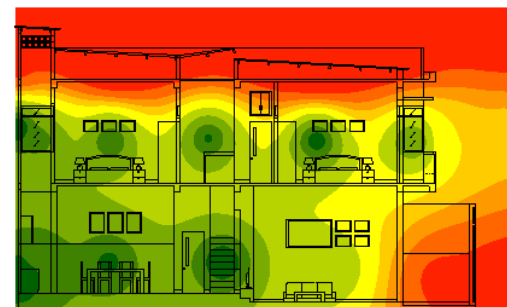
Figure 17. The two-facade microclimate analysis diagram
(Address: No. C25/2, 449 street, Tang Nhon Phu A Ward, District 9, HCMC.)
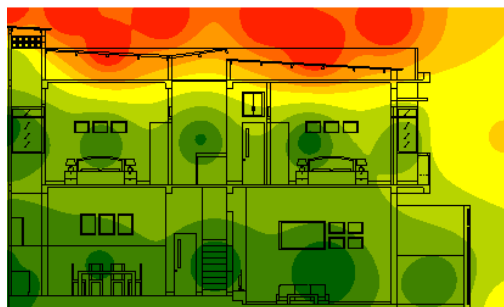
Figure 18. The one-facade thermal interpolation diagram on the coolest month of year
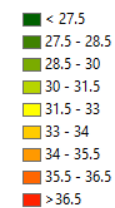
(Unit: °C)

Figure 19. The one-facade thermal interpolation diagram on the hottest month of year

- Due to the small backyard and a skylight at the bottom of the staircase create a continuously air circulates inside house. Therefore, room temperature is stable.
- The roof is designed in two layers so the room temperature is still less affected, and still gives the owner comfort in whole year especially in hottest season. At the coolest time, most of the house is heated only on the roof. At the hottest times the attic rooms are only slightly affected
- The bedroom at the front facade have the system of sunshades and flap which are limit the effect of heat radiation and increase the air circulation in the room.

This building creates pleasant feeling for the users, solves the problem of internal ventilation and has created effective insulation. No additional cooling devices such as fans and air conditioners are needed in this building. So, the power consumption is very low.

3.3.2. Two-facade row house
The research site is a 4-storey building located at the corner of the intersection. One facade looks towards the west, another looks towards the south. The two sides are adjacent to the existing neighbor's house, the two others side faced with an intersection of 10m and 20m road. The opposite buildings are only 2 - 3 floors.
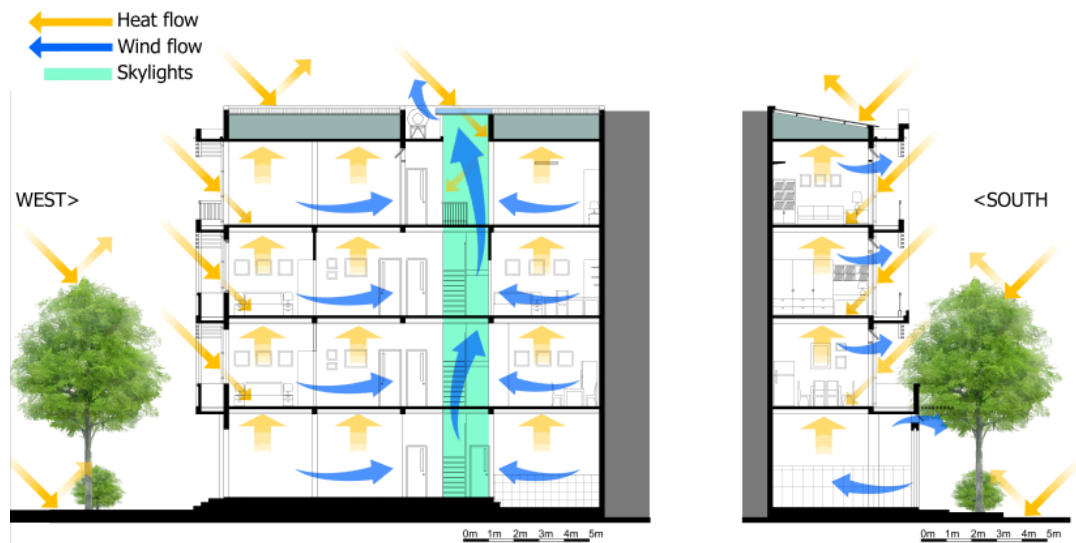
Figure 20. The one-facade microclimate analysis diagram
(Address: No. 74G, Lang Tang Phu street, Tang Nhon Phu A Ward, District 9, HCMC.)
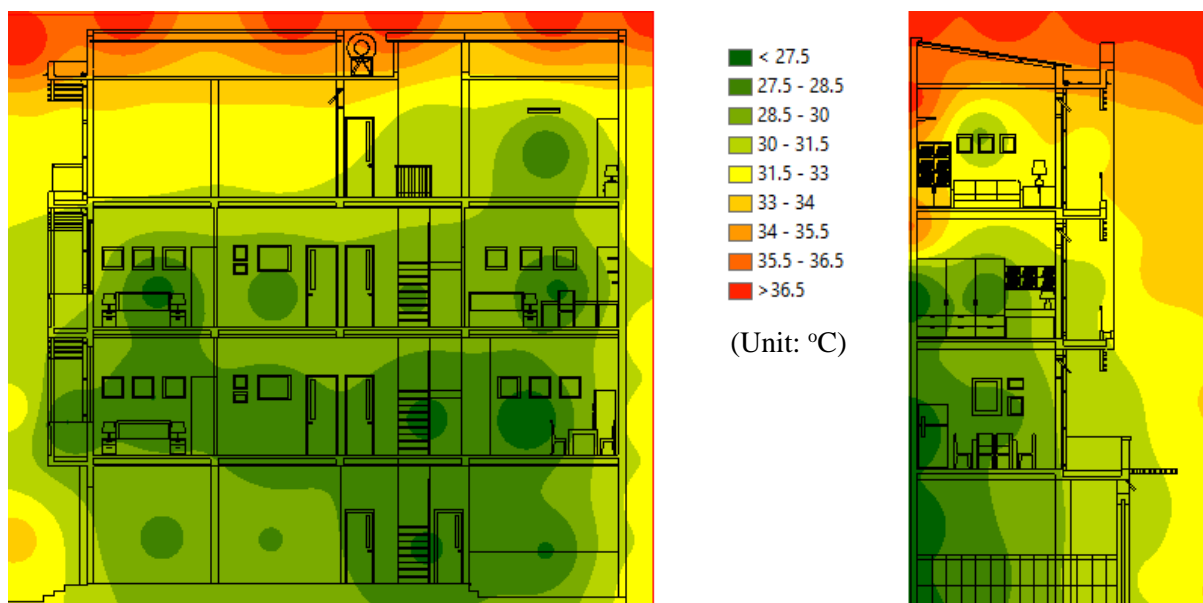
Figure 21. The two-facade thermal interpolation diagram on the coolest month of year
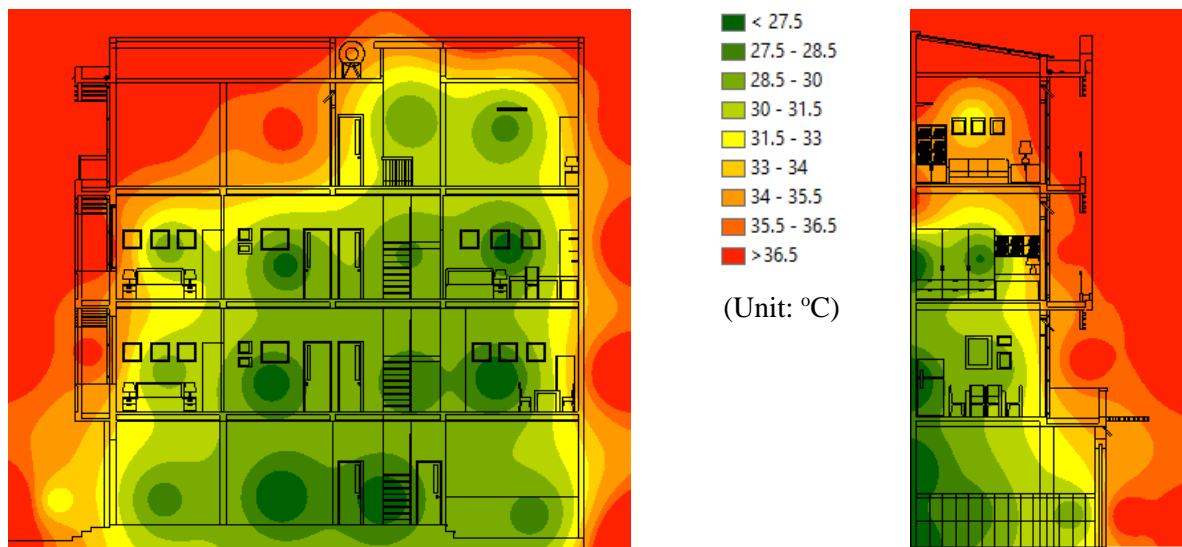
Figure 22. The two-facade thermal interpolation diagram on the hottest month of year

- Because the height of building is higher than the neighbouring buildings, the building easily catches the wind. The main wind direction is East - South and West - South.
- Because of the large, deep and closed balconies, sunlight at noon and in the afternoon only affects a small part of the wall surface. In addition, the walls are built in three layers for the higher thermal insulation.
- The windows and doors are designed to increase the air circulation in the room
- There is no wall on the rooftop. The function of this area is mainly for relaxation, planting trees. That is the reason why the thermal interpolation diagram shows the high temperature there. The indoor environment is slightly affected by heat; both are in the comfort zone.

Although the building is located in a disadvantageous micro climate position, the calculating disadvantage to give the suitable design is needed to overcome these weaknesses. Indoor lighting is reduced in capacity by utilizing natural light as well. Room temperature is always comfortable by the air circulation so that the owner does not have to use fans or air conditioning most of the time during the day. Therefore, the power consumption is always low in comparison with the same type of building.

4. Discussion

Through analyzing samples of row houses in Tang Nhon Phu A Ward, District 9, the authors summarize the issues affecting energy consumption and solutions as follows:

Table 2. The summarize of solutions and results of the row house in research area

Type of row house	Status quo	Solutions and results
One-facade row house	- Narrow width, short length. - No ventilation. - Lack of natural light. - One-layer rooftop.	- Add the skylight in the staircase space for natural lighting and ventilation - Add a small back yard - Installation of sunshade facade. - Design for a two-layer rooftop => Room temperature is stable, less affected from outdoor temperature, increased ventilation. No additional cooling devices such as fans and air conditioners are needed. The power consumption is very

		low.
One-facade row house	- Narrow width, short length. - Increasing the surface area of the building is directly influenced by solar radiation - One-layer rooftop	- Balcony surrounding the housing facade are needed, - Additional sunshade was proposed to add outside of building - Create a roof door at the staircase space to vent inside the house. - Use high window and door with the flap window above. - Use a thick 3-layer wall => High ability to receive wind. The large, deep and closed balconies have the effect of blocking sunlight at noon and in the afternoon, reduce heat absorption from the wall surface. => Room temperature is stable, less affected from outdoor temperature, increased ventilation. No additional cooling devices such as fans and air conditioners are needed. The power consumption is very low.

Because of many owners' financial conditions or habits, they are willing to eliminate the microclimate recommendations though they penetrate the impact of the environment on the space of the building. They accept the use of additional equipment to overcome the problem immediately. The result is the owners not only have to pay a big amount of money to operate but also for the maintenance cost, healthcare.

Actually, it is difficult to choose a place with favorable natural conditions to build a house. But when the designer and the owner share the same point of view, it is a good starting point to come up with the best solutions.

In order to offer the optimum solution consistent with the habits of using electrical appliances, it is necessary to evaluate the individual needs of the building, and then based on the actual conditions to provide the appropriate solution.

5. Conclusion

The results show that the effectiveness of the proposed solutions in comparison with the typical housing in research area. The interior space is always ensuring a proper indoor temperature. The gap between indoor and outdoor temperatures on the two samples of houses is very different. The rooms are all get the natural light.

The form and suitable material were selected carefully in accordance with the structural conditions and construction standards. These materials are mass-produced, and the installation method is not too complicated, so it is easy to apply commonly everywhere.

The weaknesses of this research are the data measurement by rudimentary tools, resulting in large errors in the measurement process; not expanded to other types of houses; is not going into the material properties for resistance to heat, or to analyze more deeply about the habit of daily use of household electrical equipment.

Nevertheless, the research topic also gives a studied direction in the global trend of energy saving. Besides that, this paper also suggests some research methods and some solutions for air circulation. This is also a good example of the application of GIS in analyzing the thermal interpolation diagram of a building.

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