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A Study on Green Building Efficiency Assessment in Thailand

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Abstract

Green Building is one of the ways to reduce energy costs. At present, Thailand has issued a building law that required building design to be energy-efficient by the standard criteria. Therefore, the designers have to assess the building to be constructed to meet the criteria that used the Overall Thermal Transfer Value (OTTV) as an indicator. However, to meet the criteria when designing, the designers have to spend more time compared to the old-fashioned design methods. The government agencies in Thailand, therefore, have developed a program to help calculate the OTTV so that the building efficiency assessments could take less time. The focus of this study was on the program usage on patterns and calculation test of the OTTV, as well as finding opportunities to develop future programs to increase the efficiency of the Green Building design by the standard. The results showed that the limitation of the OTTV calculation in terms of much time-consuming was since the program pattern used was Waterfall. Additionally, the limitation of the analysis of large buildings with high complexity was also a great challenge. For further program development for simplicity of use, the program patterns should be distributed by the Agile System, which would be beneficial for designers.

Disciplinary: Civil Engineering & Architectural Science, Green & Sustainable Energy.

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1 Introduction

Currently, many countries around the world are concerned about changes in energy security. The definition of security is a feeling of safeness against both mental and physical threats. Therefore, energy security is a condition that does not pose any threat to energy. It can be scaled up to having the resources to generate sufficient energy to meet the needs of current and future citizens within a limited budget (IEA, 2021). As a result of this concern, many countries have realized to reduce energy consumption to reduce costs and want their people to continue to use energy as long as possible. Thailand is one of many countries that are aware of this issue and have been trying to plan various policies from the past to the present to achieve energy savings in all sectors, including the industrial sector, transport sector, and tourism, etc. One of the sectors with relatively high energy consumption is the building and residential sectors, with the building energy consumption ratio compared to the total energy consumption in the country at 15.1% (Mangvititkul, 2005). This means this is the third-largest ratio, after the industrial and transportation sectors (Department of Alternative Energy Development and Efficiency (DEDE), 2016b). Most of the building's energy consumption is the use of the air-conditioning system since Thailand is located near the equator, resulting in the relatively high average temperature and humidity (Srivanit & Kazunori, 2011). Most people who stay indoors will feel the heat as the heat from the outside moves directly into the building, generating high energy consumption from the air conditioning system and resulting in high energy costs (Tochaiwat et al., 2020). As a result of the mentioned reasons, the government has set up a policy to control buildings by enacting legislation that requires buildings designed for new construction or buildings that are going to be modified to be designed to prevent external heat from entering the building by the criteria specified by the law set to reduce the use of air conditioning systems in the building. Therefore, those buildings must pass the standard criteria of pre-construction inspection before the construction permission. The law is called Building Energy Code (BEC).

For the background of the building energy law in Thailand, the Ministry of Energy under the Department of Alternative Energy Development and Efficiency (DEDE) has set the BEC criteria for inspecting buildings according to the requirements referenced to the standard by determining the type, size, standard, criteria, and design method of the building for energy saving in 2009, effective on 20 June 2009 (BE 2552). It is to be enforced under Section 8 of the Building Control Act 2009 (B.E. 2552) and the Energy Conservation Promotion Act (No. 2) 2007(BE 2550) to be effective in regulating the design of buildings that are submitted for construction or modification permits, with an area within that building from 2,000 square meters or more, divided into 9 types of buildings: 1) health facilities under the sanatorium act 2) schools 3) offices 4) condominium under the condominium act 5) assembly buildings under the building law 6) theaters building under the building law 7) hotel buildings under the hotel act 8) service buildings under the entertainment place act and 9) department store buildings or shopping center. All the building types are classified according to the time of daily energy use. In addition, the Department of Alternative Energy

Development and Efficiency (DEDE) has classified the building types into 3 groups: 1) educational institutions and office buildings 2) theaters, shopping malls, service places, and assembly buildings, and 3) health facilities, condominiums, and hotels. These buildings must be designed by energy conservation standards, criteria, and calculation methods as specified by the Ministry. The consideration of the BEC criteria in Thailand is based on the building envelope as it is like a shield to prevent the heat from outside the building that may enter the building. The effectiveness of the building envelope depends on the material used for the construction, thickness, number of layers, material color, and other physical characteristics (Jeyasingh, 2010). The efficiency of the building envelope is often considered using an indicator called the Overall Thermal Transfer Value (OTTV). For consideration of the heat that passes through the wall, the Thai standard will assign OTTV for all 3 groups of buildings, classified by the time of energy use of each building type which the OTTV does not exceed the standard shown in Table 1.

Table 1: Minimum Standard for the Building Design to Save the Energy

Building Types	OTTV (Watt/Square Meter)
1. Schools and Offices	≤ 50
2. Theaters, Shopping Malls, Service Centers, Department Stores, and Assembly Building	≤ 40
3. Hotels, Health Facilities, and Condominium	≤ 30

Source: (Department of Alternative Energy Development and Efficiency (DEDE), 2016a)

When calculating OTTV manually, there is a complex and error-prone principle, as OTTV is not only considered for material aspects but also the direction of the layout, the differences of solar in different seasons, transparent wall space, electrical, lighting and heating systems, indoor air conditioning systems, zoning, and the size of the interior living space, etc. Consequently, for the more accurate and standardized calculations, the Department of Alternative Energy Development and Efficiency (DEDE) has developed a program called the BEC program for evaluating buildings to be submitted for a construction permit, resulting in more convenience of the calculation. However, many users still find it difficult and complex to use the BEC program because they have to take some time to explore and complete; also, there are limitations for evaluating buildings with complex structures. Therefore, in this study, the patterns for consideration of Green Building are carried out through the BEC program as an example of future users.

2 OTTV Calculation for the case of Thailand

The calculation of OTTV consists of 2 main parts: 1) opaque wall and 2) transparent wall. The opaque wall can be calculated straight forward, but the transparent wall is complex because the direction of sunlight that may pass through the transparent wall has to be considered, causing the possibility of heat to pass through the building. Hence, there are more variables used to calculate the transparent wall. This can be expressed as

$$OTTV = (U_w)(1 - WWR)(TD_{eq}) + (U_f)(WWR)(\Delta T) + (WWR)(SHGC)(SC)(ESR) \quad (1),$$

where $OTTV$ is the overall thermal transfer value of the wall side for consideration (W/m^2).

U_w is the coefficient of overall thermal transfer of the opaque wall (W/m^2.c)

WWR is the ratio of the area of the transparent window to the total area of the wall for consideration

TD_{eq} is the equivalent temperature difference (℃)

U_f is the coefficient of overall thermal transfer of the transparent wall or glass ($W/m^2.℃$)

ΔT is the temperature difference between inside and outside of the building (℃)

$SHGC$ is the coefficient of heat from solar radiation transmitted through the transparent wall.

SC is the coefficient of shading devices

ESR is the quantity of sunset radiation that affects the thermal transferred through the transparent wall (W/m^2)

The meaning of the OTTV obtained from Equation (1) is that the higher the OTTV, the more thermal from outside entering the building's wall, which will adversely affect the energy efficiency of the building (Chan & Chow, 2014). Therefore, the OTTV must be controlled to not be too much. The calculation of each variable in Equation (1) can be classified into 3 groups.

1) The group of variables calculated from the physical properties of the materials

These variables can be simply calculated because they are the physical properties of the material that are documented, such as thermal conductivity coefficient, thermal resistance, size, area, thickness, etc. The variables in this group are U_w, WWR, and U_f, which are expressed as Equations (2), (3), (4), (5).

1.1) For Uw and U_f

$$U = \frac{1}{R_T} \quad (2),$$

$$R_T = R_o + R + R_i \quad (3),$$

$$R = \frac{\Delta x}{k} \quad (4),$$

where U is the coefficient of overall thermal transfer of the material ($W/m^2.℃$)

R_T is the thermal resistance of the material ($m^2.℃/W$)

R_o is the thermal resistance of the outer material ($m^2.℃/W$)

R is the thermal resistance of the middle material ($m^2.℃/W$)

R_i is the thermal resistance of the inner material ($m^2.℃/W$)

Δx is the material thickness (m)

k is the thermal conductivity of the material ($W/m^2.℃$).

1.2) For WWR

$$WWR = \frac{total\ area\ of\ the\ transparent\ wall}{total\ area\ of\ the\ side\ wall\ considered} \quad (5).$$

2) The Group of Variables Obtained from a Conditional Reference Source

These variables can be obtained from the government tables, books, or manuals distributed to assessors (DEDE, 2016a). The values obtained will vary depending on the conditions of the building, such as the angle of the wall, the inclination of the building from the north, the color of the material, etc. The variables in this group are TD_{eq}, ΔT, SHGC, ESR.

3) The Group of Variables that Requires In-Depth Analysis

For this group of variables, an in-depth analysis is needed to calculate the values because the calculations are based on a wide range of periods, directions, and shapes of materials. The variable that falls into this group is SC. The formula used to calculate the SC value is not complicated at all, as expressed in Equation (6).

$$SC = \frac{E_{ew}}{E_{et\theta}} \quad (6),$$

where E_{ew} is the quantity of solar radiation that passes through the actual transparent wall ($W/m^2 \cdot day$)

$E_{et\theta}$ is the quantity of solar radiation without the transparent wall ($W/m^2 \cdot day$)

In other words, the SC value is the percentage of solar radiation that passes into the transparent wall on the considered side. If only consider this, it might sound simple to calculate. However, the E_{ew} and $E_{et\theta}$ require knowledge of geography to calculate the shadows that pass through to the actual transparent wall at different times of the year, which Equation can be expressed as Equations (7) and (8), including the shape of the shading devices of each different building (Maipatana, 2016).

$$E_{ew} = \left(A_{fu}/A_f\right)(E_{es})(cos\theta) + (E_{ed})\frac{(1+cos\beta)}{2} \quad (7),$$

$$E_{et\theta} = E_{es}cos\theta + E_{ed}\frac{(1+cos\beta)}{2} \quad (8).$$

Where A_{fu} is the area of the window that is exposed to the sun (m^2)

A_f is total window area (m^2)

E_{es} is the quantity of direct solar radiation (W/m^2)

E_{ed} is the quantity of diffuse solar radiation (W/m^2)

$cos\theta$ is the angle of the sun relative to the vertical window (degree)

$cos\beta$ is the angle of the sun relative to the horizontal window (degree)

From the calculation characteristics, each day, if the calculation is made on the assumption that the sky is open and the sun is visible all day, the angle from the sun will change over time. Therefore, calculations in 1 year will have 365 results, resulting in many calculations for OTTV. In addition, the assessor must find the maximum OTTV as a reference value; also, this is coupled with the need to continually assess many buildings under construction, causing the assessor to rely on a program that helps calculate the OTTV instead of manually calculating. At that time, the assessor will use a program to calculate the overall thermal transfer through the building envelope and the energy consumption within the building via Overall Thermal Transfer Value and Energy Estimation (OTTVEE). However, the program has not yet been able to enforce effective reductions in energy consumption. For this reason, the DEDE in conjunction with Able Consultant has developed a program called Building Energy Code Software or BEC (Jamniandamrongkarn, 2012).

3 Method

In this study, a trial run of the BEC program's latest version 1.0.6, developed from the Civil Service Commission for OTTV evaluation of the building, was conducted. The buildings selected for testing were from the construction designs from the house plans that the Department of Public Works and Town & Country Planning under the Ministry of Interior have distributed to the public to use for free. The plans can be shown in Figure 1.

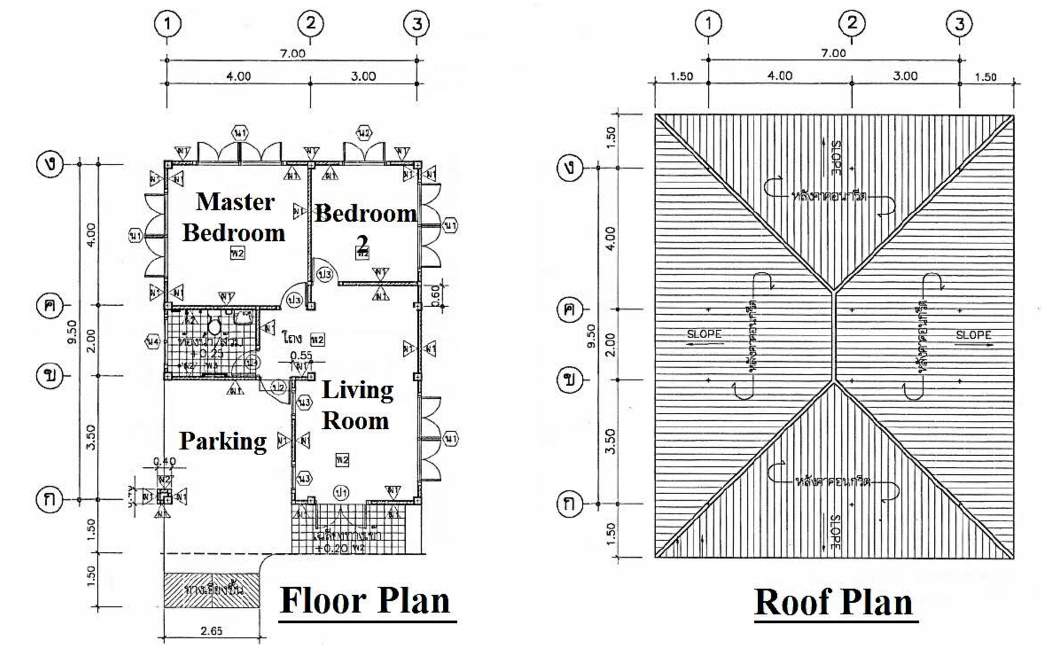

Figure 1: Sample of House Plans for Testing the OTTV in the BEC Program.

After selecting the construction plans, the study using the BEC v.1.0.6 program was conducted, the program's working pattern of the OTTV calculation is shown in Figure 2.

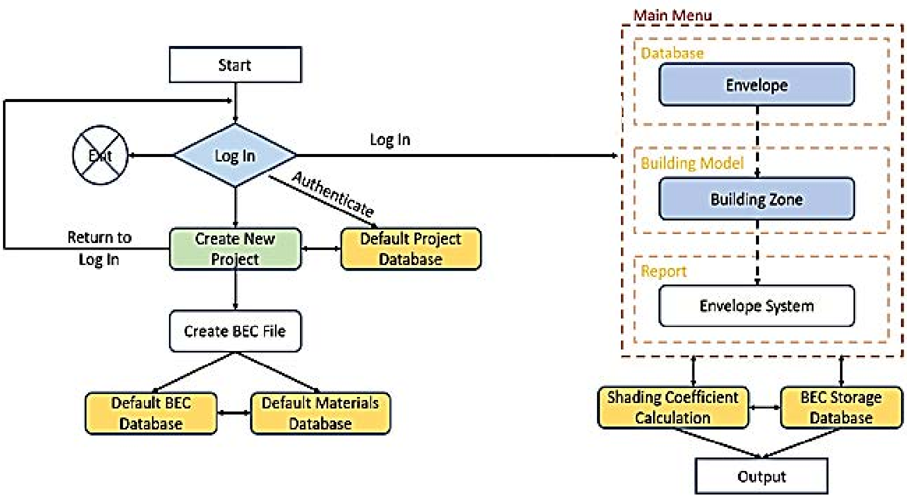

Figure 2: The Structure of BEC v.1.0.6 Processes.

According to Figure 2, the functionality of the BEC v.1.0.6 program consisted of the structure used to collect data, including material list and angle table. The calculation of OTTV could be divided into 4 subsections:

1) Log-in and Project Creation
2) Data Input and New Data Creation

3) Determination of the Area and Building Zoning
4) Calculation Results

For the scope of this study, the setting of the house was assumed to be in Chiang Mai Province, North of Thailand. The wall material was bricking white-washed, which could be commonly found in Thailand. About the OTTV calculation using the BEC v.1.0.6 program, case studies were divided into 8 cases with details as shown in Table 2.

Table 2: The Division of Case Studies for the Trial of the BEC v 1.0.6

Case No.	The angle of Building to North and South (degrees).	No. of Wall Layers	Wall Thickness (cm.)
1	0	1	10
2	0	1	20
3	0	2	10
4	0	2	20
5	45	1	10
6	45	1	20
7	45	2	10
8	45	2	20

The case studies were divided according to historical data referred. It was found that the main factors resulting in the high variation of OTTV were the direction of the building envelope, wall thickness, number of layers, and the properties of the transparent wall (Chow & Yu, 2000). The properties of the transparent wall were already specified by the construction plans, so there was no need to make changes. Consequently, this study divided the case studies by changing only 3 factors: the building's angle to north and south, the number of wall layers, and the total thickness of the wall to study how much the OTTV direction or results would change.

Using the BEC v.1.0.6 program, the data input needed to be divided into much different information, including the list of materials, the patterns of wall layer designation, and the division of internal space, etc. Most steps were to put information into the program, which was a very important step for OTTV calculation. In case of wrong data input, the program would show no notification, causing distorted values or calculations to the users. Because of that, before saving the data every time, the users need to check the validity first. The input window is divided into three sections: 1) List of Materials 2) Wall Layer Designation, and 3) Building Zoning. The interface of sections 1) and 2) can be shown in Figures 3 and 4, respectively.

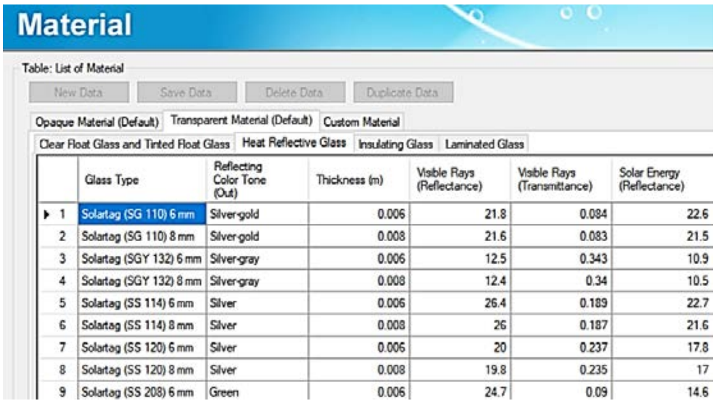

Figure 3: The part of the interface of the BEC v.1.0.6 displaying the Materials.

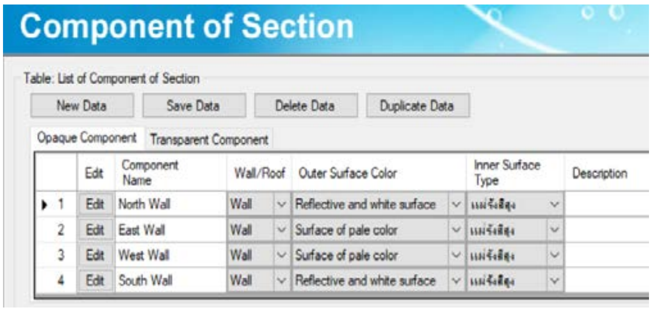

Figure 4: The part of the interface of the BEC v.1.0.6 displaying the wall layer designation.

In the operation window, on the right-hand side of Figure 3, there are different options for entering data into the program's repository. It includes details of materials and tools of opaque walls, transparent walls, cooling systems, and solar systems, etc. In this study, only the part related to the building envelope to find OTTV, that was the Envelope command, was utilized, consisting of 4 subcommands: Material, Component of Section, Section of Wall, and Wall.

In the Material Command, there is information on the standard materials that are widely used in Thailand. The data of these materials are already contained in the program's database. If the users would like to enter the information for a new material that does not yet exist in the original database, this command is applicable to add new material information to the program. Importantly, the data for the newly created material must clearly state the category and type (opaque, transparent, or air vent), and the material's convection, density, and specific thermal values must also be included. For the wall layer designation, users must add the wall layer and choose the wall materials from the database in the program. Additionally, the physical properties of the walls must also be determined, such as the color tone of the wall surface and the radiation of materials used to build walls, etc. After filling in all four directions, the next step is step 3). It is to do the zoning to place the air conditioning system in the room according to the construction plan. In the operation window of zoning, the user must calculate the space or area before entering the value into the program. This is another step that requires careful inspection because if it is to assess a building that has a lot of people use, such as a hospital or a shopping mall, space management plays a really important role (Varpu & Patrik, 2007). The interface when zoning is shown in Figure 5.

Figure 5: The part of the interface of the BEC v.1.0.6 displaying the Building Zoning.

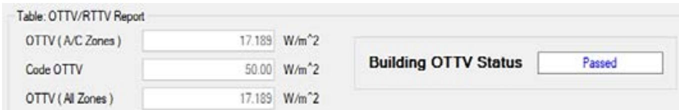

Figure 6: The Interface of the BEC v.1.0.6 displaying the calculation result of OTTV.

On the Building Zone window, the users are required to include the wall area on that side and must select the type of wall created in Part 2) into the building envelope of each room. However, the wall with data input into the program is just the surrounding wall attached to the outdoor area exposed to sunlight. Meanwhile, the interior walls used to divide different rooms do not need to be put into the program because they are not exposed to the heat from the outside of the building. After completing all data entries, the program will calculate the OTTV of each wall side and display the status of whether it meets the Thai standard or not. The interface is presented in Figure 6, but the results of the calculation for each case are explained in the next chapter.

4 Result and Discussion

Regarding the use of the BEC v.1.0.6 to calculate the OTTV by the Thai standard criteria, using construction plans from the Department of Public Works and Town & Country Planning under the Ministry of Interior located in the Chiang Mai area, the case studies were divided into 8 cases as presented in Table 2. As a result, the BEC program calculated and showed the OTTV as Table 3.

Table 3: The Results of OTTV Calculation in 8 cases via the BEC v.1.0.6 Program

Case No.	The angle of Building to North and South (degrees)	No. of Wall Layers	Wall Thickness (cm.)	OTTV
1	0	1	10	39.15
2	0	1	20	27.76
3	0	2	20	27.87
4	0	2	30	23.45
5	45	1	10	39.48
6	45	1	20	27.97
7	45	2	20	28.11
8	45	2	30	23.63

Referred to the results presented in Table 3, there were 3 interesting topics found regarding the different OTTV of each case, which could be discussed as follows.

2. The change of building direction

The change of the building direction slightly affected the calculation of OTTV. Buildings positioned parallel to the north-south direction (0 degrees to the north-south) had lower OTTV than buildings positioned at a 45-degree angle to the north-south. This was because the location in Thailand has the hottest time of the day in the afternoon when the sun is in the southwest line (Srivanit & Hokao, 2012). The walls in the southwest were directly exposed to sunlight, resulting in higher OTTV. By comparison case 1 and case 5, the case 5 OTTV was 0.84% higher than in case 1.

3. The Increase in the Number of Wall Layers

From the calculations via the program, it was found that if the number of wall layers increased, the calculated OTTV would be slightly higher, which may contradict the supposed fact that double-walls tended to prevent the thermal better than single-layer walls. This was due to the construction of a double-wall, which often increased the wall thickness by almost 2 or more times compared to the original method. Therefore, if considering the requirements for the same wall thickness, it would be found that a single wall was slightly more thermally resistant than a double wall with air vents. For instance, in cases 2 and 3, the double-wall with the same thickness as the single wall would have the OTTV higher than 0.40%.

However, if the double wall thickness was greater than the single wall, the OTTV of the double-wall was much lower, which made sense to say that the double-wall could reduce the external heat that could enter the building. When comparing cases 2 and 4, it was found that the more thickness of double-wall had the OTTV that was 15.53% lower than that of a single wall.

4. The Increase of Wall Thickness

For the increase of the wall thickness, it was found that both single-layer wall and double-layers wall in all directions, if there was an increase in thickness, the OTTV would decrease significantly. It was reasonable because increasing the wall thickness would reduce the U value, resulting in lower OTTV as well since the U value directly varied with the OTTV. For single-layer walls, if doubling the thickness was twice, the OTTV would be reduced by 29.09%.

5 Conclusion

For the study of the model efficiency criteria for the assessment of the green building in Thailand, the OTTV calculated from BEC v.1.0.6 program could be utilized for the building energy efficiency indicators accurately. However, there are some issues and limitations of the use of the program found in this study. Since the functionality of the program is a step-by-step or Waterfall, work must be completed one by one before proceeding to the next process, resulted in the problem with lots of time-consuming to calculate, just as the user has to fill in a lot of information manually. If the project is large and the construction is complex, the utilization of the program may take a little less time than doing the manual calculations. Moreover, if the pattern is changed, the user will have to repeat the work. For example, this study comprises eight case studies, users had to do eight repetitions of work, exponentially increasing the time. Therefore, if there is a future development of this program for legal use in the future, the program developer should use the Agile System, which is the integration of several parts which will allow designers to calculate faster because they can specifically fix only the problematic parts or changed designs.

Regarding the limitation of use, it was found that the program can calculate the OTTV of a straight wall effectively. However, the calculations of the building with lots of overhangs may not be valid or precise. This is because at times the protruding part of the building blocks the direction of the sunlight, causing shadows to cover some of the walls, but the program displays the result that the wall that is shaded is exposed to the sun all the time, resulting in the greater values calculated than the reality that the designer intended to block sunlight. This limitation is an issue that the designers have a lot of difficulty in working with. The solution may be the creation of a detailed Sun Analysis based on the location of the construction site in the next version of the BEC program to make the calculation of OTTV as accurate as possible.

There are still some limitations of the use of BEC v.1.0.6 for OTTV calculation in terms of the operation and the analysis of complex buildings. If the program developers could let the users separate the work parts and have the correct shadow analysis, it would be of great benefit to the designers of green buildings in Thailand.

6 Data Availability Statement

The data for this study can be available upon a request made to the corresponding author.

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