



# Systematic Review of Energy Building Simulation Processes in Thailand

Nuttapon Chanpichaigosol<sup>1,2\*</sup>, Damrongsak Rinchumphu<sup>2</sup>, Chinnapat Buachart<sup>2</sup>,  
Chatchawan Chaichana<sup>3</sup>, Non Phichetkunbodee<sup>1,2</sup>

<sup>1</sup> Construction Engineering and Management Program, Faculty of Engineering, Chiang Mai University, THAILAND

<sup>2</sup> Department of Civil Engineering, Faculty of Engineering, Chiang Mai University, THAILAND

<sup>3</sup> Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, THAILAND

\*Corresponding Author (Tel +66-949535592, Email: [ch.nuttaponn@gmail.com](mailto:ch.nuttaponn@gmail.com)).

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SketchUp, .

## Abstract

The purpose of this study was to find suitable processes for the analysis of the energy consumption of buildings to be aligned with the process of Building Information Modeling (BIM). Since many approaches had not been evaluated for their appropriateness and ease of use of energy building simulation processes in Thailand, it is necessary to repeat the process of the waterfall model from the beginning when any adjustment is required. Therefore, in this study, the authors selected the processes which were able to actualize energy analysis systemically and were able to perform agile system modification, resulting in a time-saving process without any rerun. A total of 17 academic articles published in international databases were reviewed to formulate a systematic analysis and an investigation of four conditions. It was considered essential that the approaches must provide a simple form of accurate energy values, simple and rapid process, familiarity for most of the users, and suitability in terms of the databases available in Thailand. The results showed that the selection of Autodesk Revit with OpenStudio and EnergyPlus was the most appropriate, which could be used as a further efficient process of analyzing the energy consumption of buildings in Thailand.

**Disciplinary:** Civil & Architectural Engineering (Green Building), Energy & Sustainability.

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## 1 Introduction

Thailand is experiencing continuous population growth (NESDC, 2019) with urban growth in both horizontal and vertical directions. 'Horizontal growth' refers to an expansion of the city's

width, with few tall buildings built but a lot of space being taken up. In contrast, the term 'vertical growth' in the urban area consists of more tall buildings and more density. Both types of development bring both advantages and disadvantages for those living in the city. Advantages are likely to include convenient and extensive transportation services. However, increased density causes ventilation difficulties. Furthermore, the radiation from the sun causes a phenomenon known as 'heat island', which directly affects the energy consumption buildings. Inevitable increases in energy consumption, and in air conditioning systems, have resulted from this accumulation of hot air. A Green Building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment (Yudelon, 2007). It is one promising solution that has been found in order to reduce energy consumption. Although they have huge potential in terms of long-term energy-saving and are environmentally friendly, the construction prices are still high. To calculate Thailand's current building energy consumption, the Building Energy Code (BEC, a difficult and complicated program), is required. In addition to BEC, a range of programs developed outside Thailand and technologies are currently used, including Autodesk Revit, Green Building Studio (GBS), Sketchup, and EnergyPlus. Although these provide fast and accurate procedures, the programs may not contain information that is applicable to Thailand. Moreover, if any work processes were conducted in a format aligned with the Building Information Modeling (BIM), then an 'agile' system (Kibler, 2019), which can rapidly change the building models for modification, is essential. A key element that affects the energy value of a building is the 'building frame': the surrounding walls of the entire building and whether they are solid or glass. Next are building accessories, such as electrical equipment, lighting, and air conditioning systems (Ministry of Energy, 2017) that directly affect the energy of the building (Tochaiwat & Likitanupak, 2017). The tools mentioned previously are continually evolving, resulting in the need for regularly updated software and work styles.

The work processes are of paramount importance for Green Building designs. Nowadays, the working processes relying on software developed outside the country need to be analyzed in order to find procedures that are suitable for Thailand. Minimum requirements must be a simple and fast form with accurate energy values, familiarity for most of the users, and suitability in terms of the databases available in Thailand. The goal of this study is to consider a number of academic reviews in international databases, including important findings indicating the systematic process of Energy Building Simulation; this information must also be analyzed in comparison to working patterns in Thailand.

## 2 Literature Review

Currently, there are five software most commonly used in construction works in Thailand. The first one is Autodesk Revit (Figure 1). It is a functional program for structural and architectural uses. Also, it is suitable for system-related work, whether it be mechanical, electrical or sanitary

(Al Doury et al., 2020). The program creates a three-dimensional building model and inserts data in the form of the Building Information Modeling (BIM) process.

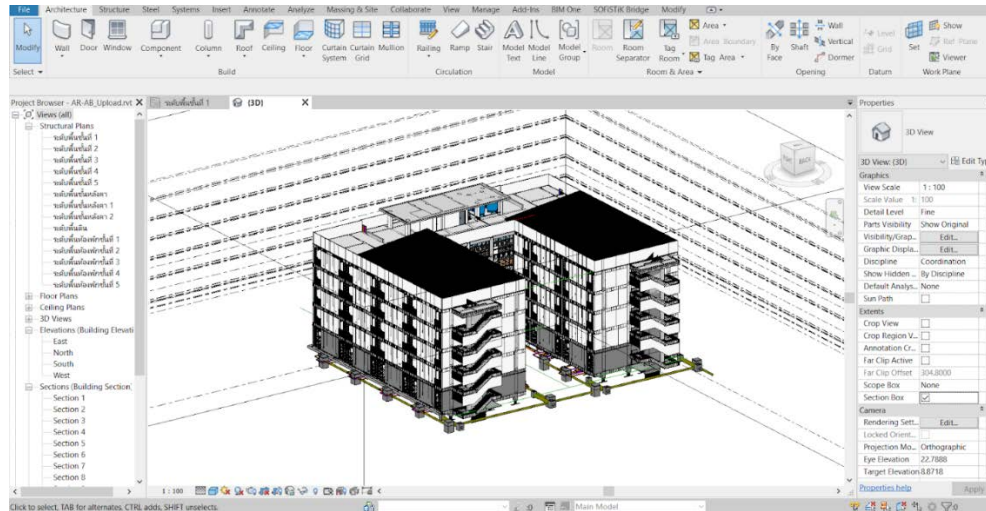


Figure 1: The Autodesk Revit Version 2020 Interface.

The next program is an add-on that comes with Autodesk Revit, the Green Building Energy Studio program (Figure 2). This program calculates the energy value of buildings, including solar energy (Figure 3). In this process, files generated by Autodesk Revit are used to simulate the energy values by determining the building type, usage time, and materials. However, the limitation of this program is the air conditioning systems because there is only an HVAC function while the Split Type is mainly used in Thailand, meaning that the Green Building Energy Studio program is not suitable for Thai users.

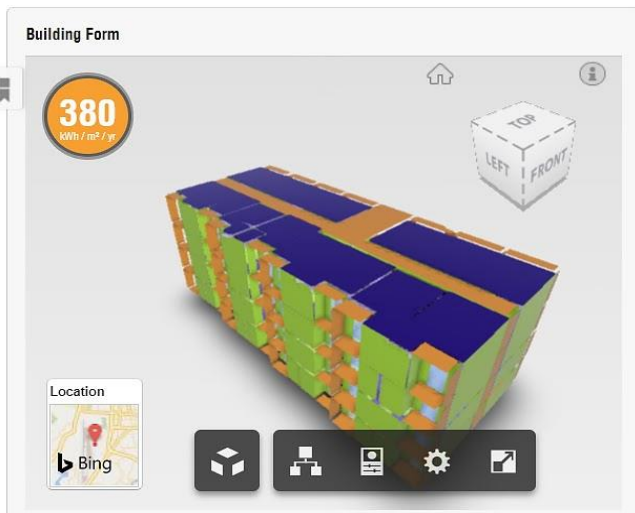
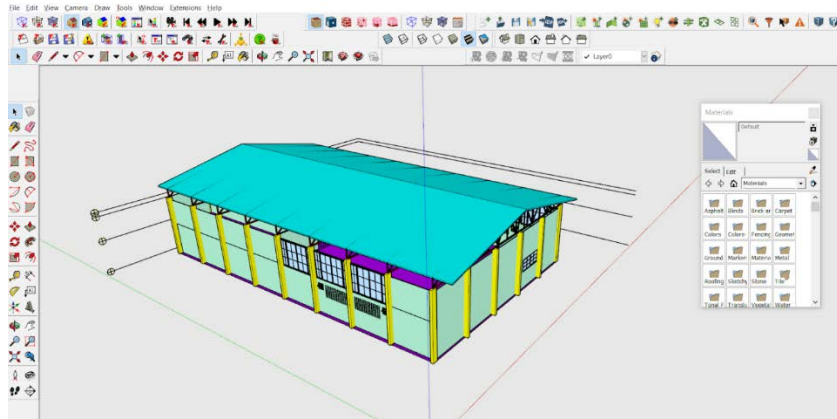


Figure 2: Interface of the Results of Energy Analysis via Green Building Energy Studio.



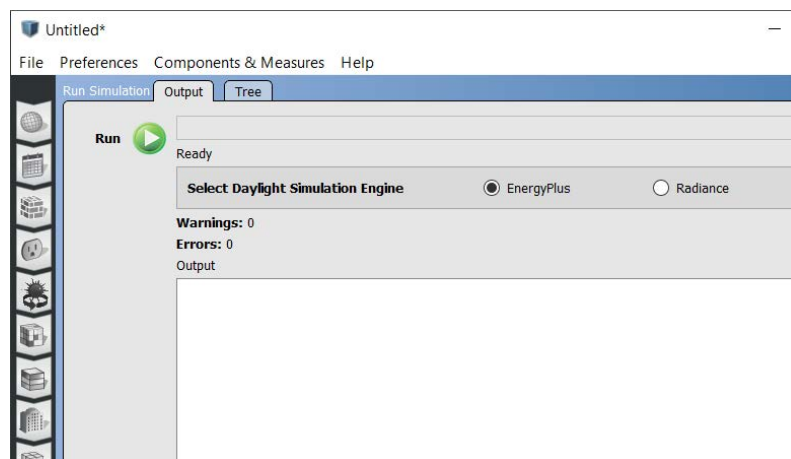
Figure 3: Example of Solar Energy Analysis.

SketchUp is widely used by Thai architects because of its ability to quickly create building models and its ability to display the results in an appealing format (Figure 4). The advantages of this program are its speed and the simplicity of learning and using it (Lertpocasombut et al., 2016). However, for fields other than architecture, other working systems are required such as sanitary systems, electrical systems, and air conditioning systems, resulting in the redundancy of the building modeling.



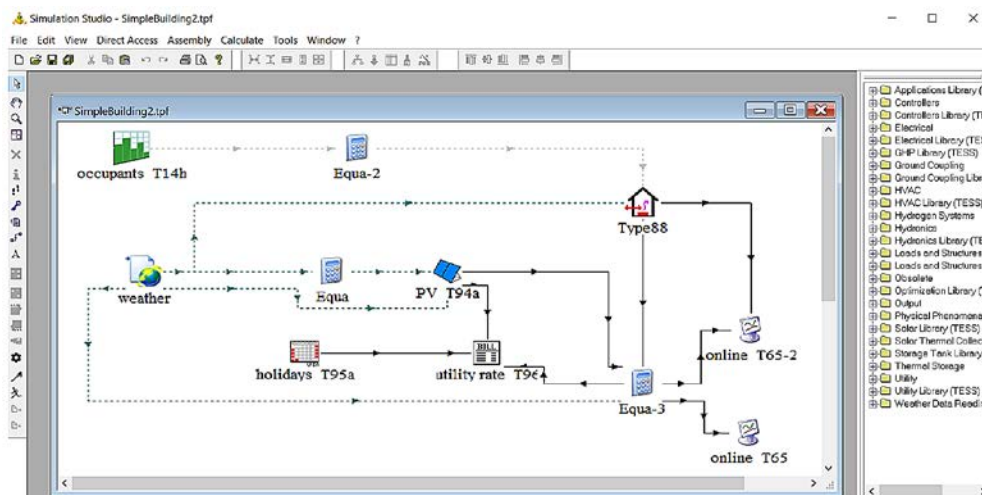
**Figure 4:** The Interface of SketchUp Creating the 3D Model.

Next, EnergyPlus is a widely used program for energy analysis, often bundled with other programs such as OpenStudio. (Kamel & Memari, 2019) (Figure 5). The design-builder enters information on materials and functional patterns of buildings before analysis with the EnergyPlus program.



**Figure 5:** Example of OpenStudio Integrating with EnergyPlus.

The last program is TRNSYS (Figure 6). This program can analyze the energy value of many systems, including power, air conditioning, or heating. However, it requires expertise for effective use (Jani et al., 2019). Models must be created via the TRNBuild program or imported from SketchUp created with Trnsys3d add-ons before using in TRNSYS.



**Figure 6:** TRNSYS - Simulation Studio Interface.



For the simulation process, in the past, construction work was shown in the form of a waterfall, also known as the Waterfall Model, a kind of hierarchical operation (Figure (7, which could not be revised after the process was completed. The advantage of this approach was that it is an ordered and structured operation, resulting in accurate forecasting of productivity and time. Therefore, this process was a fundamental tool used to determine the duration of a project. On the downside, if the design were modified or revised on a large scale, it could result in the project failing due to the re-initialization of work, leading to considerable delays )Mohamed & Moselhi, (2019.

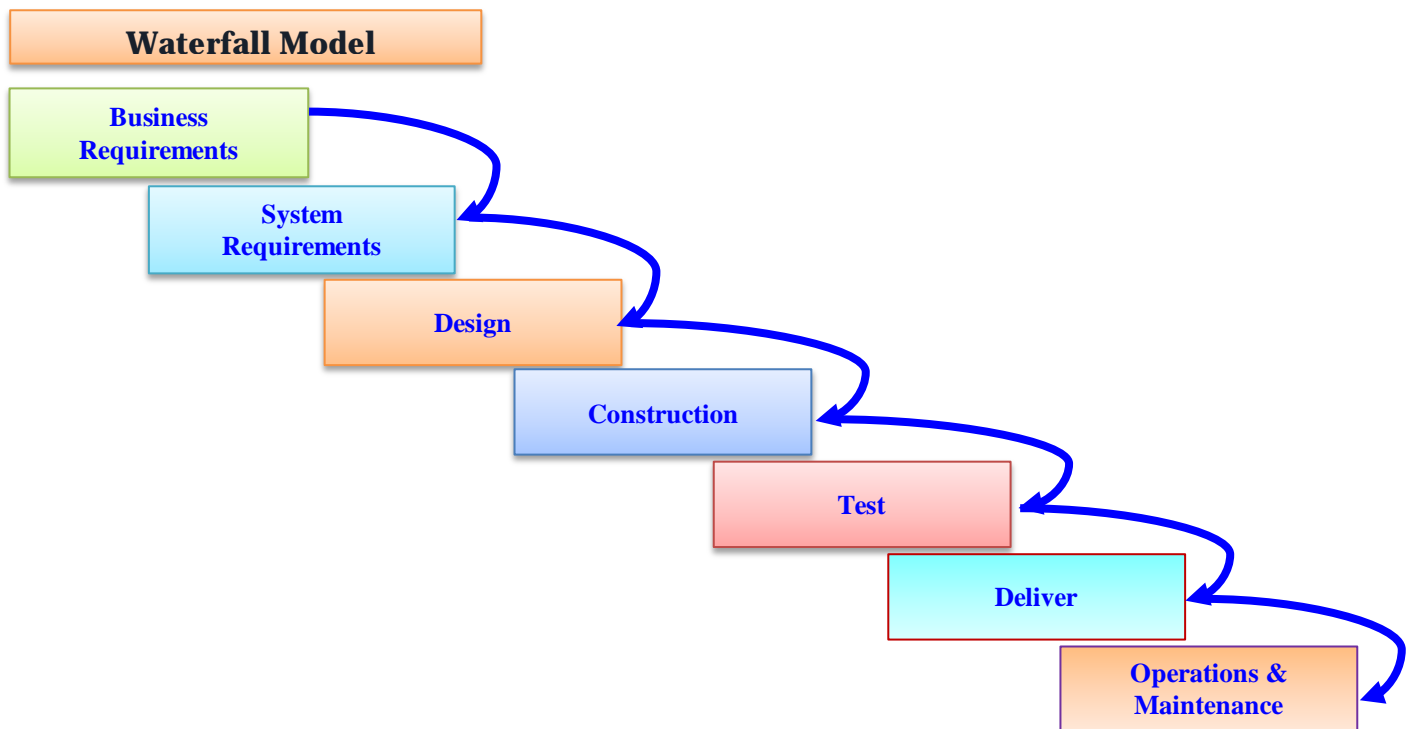


Figure 7: Waterfall Model of Construction Process (Adapted from Mohamed & Moselhi, 2019).

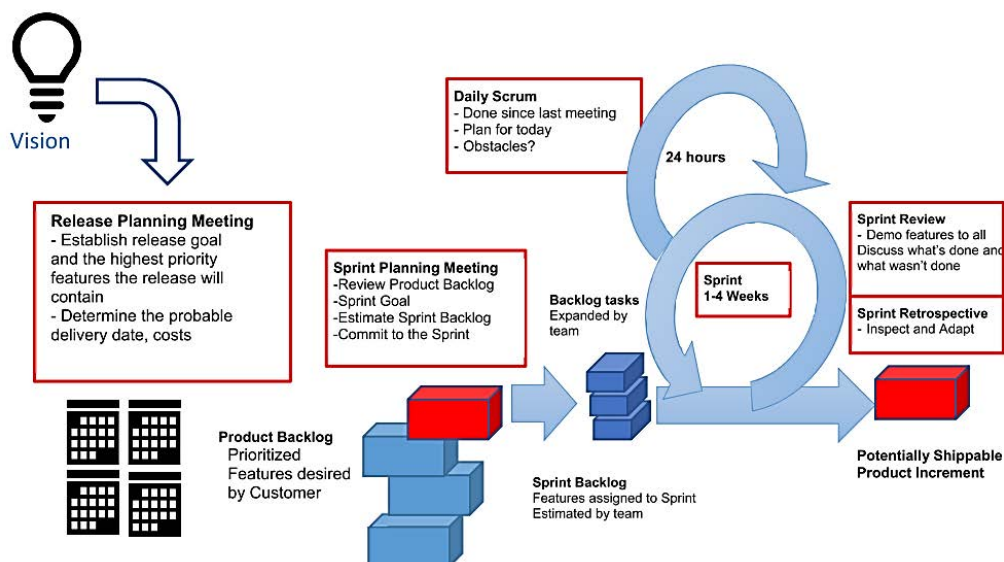


Figure 8: APM Working Process (Kibler, 2019).

Due to the frequent problems with the waterfall model because of frequent modifications, working styles have been developed into a process known as Agile Project Management (APM). This provides both a solution to the major problems of the waterfall model and a suitable process for

projects where changes in the form of the project itself or even the environment are possible, as shown in Figure 8.

APM is a process that provides constant updates to each other's data, making it simpler when the data need changes, and all parties will always receive new information. APM works in an always-up-to-date and fluid form of data without the necessity to go back and simulate new models. It is clear that in Thailand only the BEC program is commonly used in energy simulation modeling because it is mandatory in Thailand. (Ministry of Energy, 2017) Moreover, the BEC process can be considered as a form of the waterfall model, meaning that it takes more time for any adjustment throughout the process. Thus, a more suitable program is needed.

### 3 Method

Building energy analysis is often used in architecture. There are many popular design programs, consisting of SketchUp, AutoCAD, and Autodesk Revit. After that stage, energy analysis is conducted via Energy Plus, TRNSYS, Autodesk Energy Simulation, or IDA ICE, for example. Every process has a file that can be interconnected, but it may not be supported by some programs. In this regard, the researchers have come up with a method for analyzing the energy values of buildings that are suitable in Thailand by using the literature review to set the conditions for use in finding a guideline for the energy value analysis of buildings. To sum up, the approach must be an agile system because it fits the BIM, is faster in terms of data speeds, and can be modified quickly. In addition, the calculation program must provide accurate energy output. Some programs run quickly but are less accurate, while others are difficult to use but very accurate. This can cause a delay in computation. Another important condition is that people in the country of use have to be familiar with the program because their unfamiliarity results in inexperience in use. The last condition is that it must be suitable for Thailand, in terms of meteorological data or construction materials. The users should be able to find, download and add whatever is necessary to the program.

#### 3.1 Data Collection

In this study, 17 academic articles published from 2016-2020 were reviewed. The keywords used were Energy Simulation, Building Retrofit, Energy Analysis, Energy Plus, Modeling and Simulation, BIM., Building Energy Simulation, Revit, TRNSYS and OpenStudio. The data were collected and summarized. and taken through the analysis process with four conditions: the agility of the system, familiarity for people working in Thailand, the accuracy of the calculation program, and appropriateness in Thailand. The results were then analyzed as in Figure 9.

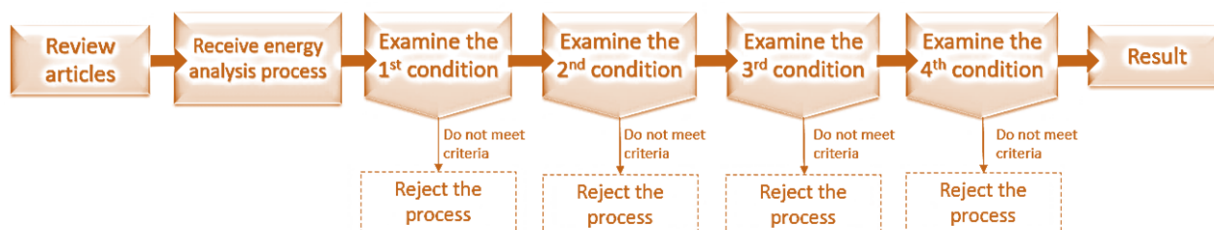


Figure 9: Operation Procedures.

### 3.2 Data Analysis

The research procedures of the 17 articles were examined to find the most widely used approaches, which are summarized in Table 1.

**Table 1: Results of the energy analysis value approaches obtained from all 17 articles.**

Program Use	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
<b>Building-energy Model</b>																	
Revit		a				a											a
Sketchup+ OpenStudio			a			a	a			a				a			
Design builder									a				a				
Sketchup + Trnsys															a	a	
<b>Energy Analysis</b>																	
Revit		a															a
Energy Plus	a		a	a		a	a	a	a	a	a	a	a	a		a	
Trnsys					a							a			a		

Remarks: 1=Kwak & Huh (2016), 2=Nugrahani et al (2018), 3=Biswas et al (2019), 4=Huelsz et al (2019), 5=Jani et al (2019), 6=Junior et al(2019), 7=Kamel et al (2019), 8=Sharif et al (2019), 9=Shen et al (2019), 10=Theresa Innocent et al (2019), 11=Troup et al (2019), 12=Ahamed et al (2020), 13=Chowdhury et al (2020), 14=de Azevedo et al (2020), 15=Mazzeo et al (2020), 16=Ramaji et al (2020), 17=Al Doury et al (2020)

## 4 Results

Regarding the results presented in Table 1, several obvious alternative methods for energy value calculation to be used in this study were summarized into five approaches as follows:

- 1) Revit + Autodesk Green Building Studio: drawing the 3D model via Autodesk Revit, then transmitted to Autodesk Green Building Studio, a program to calculate energy values.
- 2) Autodesk Revit + Sketchup + OpenStudio + Energy Plus: 3D modeling via Autodesk Revit, transmitted to Sketchup, then OpenStudio plugin was used in Sketchup to input building energy data and analyze energy values by Energy Plus.
- 3) Autodesk Revit + OpenStudio: 3D modeling via Autodesk Revit, transmitted to Sketchup, then OpenStudio plugin was used in Sketchup to input building energy data and analyze energy values by Energy Plus.
- 4) Sketchup + OpenStudio: 3D modeling via Sketchup and using OpenStudio plugin to input energy data and analysis by Energy Plus.
- 5) Sketchup + TRNSYS: Modeling via Sketchup and exporting files to TRNSYS to input energy data and analyze energy values in the TRNSYS program itself.

After five approaches were provided, the methods in each format were compared according to the criteria previously mentioned. The first criteria must be an appropriate working model, known as Agile System, which means that the approaches including the waterfall model were rejected (direction 4 and .5) After that, the accuracy of the program was measured. Most of the existing programs had no differences in terms of accuracy; therefore, they were compared by the next criteria, the familiarity of users in Thailand. It could be indicated that TRNSYS was the only program that was rarely used in Thailand because this program required a relatively high level of expertise, making it difficult to use. The last criterion was the appropriateness of materials in the country. It could be concluded that only Autodesk Energy Simulation was not widely available for use. Regarding the study processes, two approaches were used to analyze the energy value:

- 1) Autodesk Revit + Sketchup + OpenStudio + Energy plus
- 2) Autodesk Revit + OpenStudio

It appears that these two approaches were very similar, making it difficult to draw conclusions about which one was better. Starting with the second approach, it was to simulate a model via Autodesk Revit and sent the file to OpenStudio, which was a shorter way than approach 2 as it could save more time. However, according to the results, the problems of the data transmission from Autodesk Revit with IFC or Gbxml files to OpenStudio still occurred, especially when writing code, resulting in missing information at some points. For instance, the first floor in the simulated model did not display properly, or there may be some missing wall materials. As a result, approach 1 was more interesting than approach 2 because it could be used to solve the mentioned problem because the missing part could be completed by Sketchup. Nevertheless, if the code could be revised in the future to be able to transmit the information smoothly, the second approach would be a more suitable alternative. In addition, this process can create a three-dimensional model. The limitation in this research is the lack of practical use due to the high costs and value of the programs. Besides, some programs require considerable expertise for them to run effectively. Further research should focus on practical uses in order to compare a) the accuracy of each model with b) creating the same model to acknowledge more about the effectiveness of the approaches.

## 5 Conclusion

Because the demand for Green buildings is increasing for reasons of long-term energy-saving and being environmentally friendly, the energy building simulation process is necessary for energy value calculation. At present, there are a variety of tools: Autodesk Revit, Green Building Studio (GBS), Sketchup, and EnergyPlus. They are programs developed outside Thailand and technologies with the advantage of having quick and accurate procedures; on the other hand, the disadvantage is that there may be no suitability in terms of the databases available in Thailand in the program, making it inappropriate and inconsistent with the work in the country. In the future, there may be a need to use more of the building information modeling (BIM) and agile systems in order to make corrections to the building model more quickly. Therefore, the researchers selected the processes that are appropriate for Thailand through four working conditions: accurate energy values, simple and rapid process, familiarity for most of the users, and suitability in terms of the databases available in Thailand. Considering the literature review of the 17 academic articles published from 2016 until 2020 under the systematically specified keywords, the key finding is that the use of Autodesk Revit together with OpenStudio and EnergyPlus is the most suitable procedure because it can be used as a systematic process of analyzing the energy consumption of buildings in Thailand, which can greatly increase the speed and accuracy of the energy calculation for the pre-construction or renovation period. Also, practical uses may result in the selection of systematic energy analysis approaches in the future.

## 6 Availability of Data and Material

Data can be made available by contacting the corresponding author.



## 7 Acknowledgment

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**Nuttapon Chanpichaigosol** is a student at the Department of Civil Engineering Faculty of Engineering in Construction Engineering and Management, Chiang Mai University, Thailand. He got a Bachelor's degree in Automotive Engineer from Thai-Nichi Institute of Technology, Thailand. His research focuses on Building Energy Simulation and Energy Analysis.



**Dr. Damrongsak Rinchumphu** is a researcher at the Center of Excellence for Natural Disaster Management (CENDIM) and an assistant professor at the Department of Civil Engineering, Faculty of Engineering, Chiang Mai University, Thailand. He has a Doctoral degree in Civil Engineering and Built Environment from Queensland University of Technology, Australia. His research focuses on Sustainability and Technology in Civil and Construction Management.



**Dr. Chinnapat Buachart** is a Researcher at the Center of Excellence for Natural Disaster Management (CENDIM), and a Lecturer at the Department of Civil Engineering, Faculty of Engineering, Chiang Mai University, Thailand. He received his Ph.D. in Structural Engineering from the Asian Institute of Technology (AIT), Thailand. His research focuses on Computational Methods in Structural Mechanics.



**Dr. Chatchawan Chaichana** is Director of the Energy Technology for Environment Research Center (ETE), an Assistant Professor of the Department of Mechanical Engineering, and associate dean of the Faculty of Engineering, Chiang Mai University, Thailand. He received his Ph.D. in Engineering from the University of Melbourne, Australia. His research focuses on Energy Efficiency, Green Building, Sustainable Development, Smart Agriculture and Management, Air Conditioning System, Energy Conservation, Heat Pump, Natural Working Fluid, Renewable Energy, Geothermal Energy, Biomass, and Gasification.



**Non Phichetkunbodee** is a master's degree student at Construction Engineering and Management Program, Chiang Mai University, Thailand. He got a bachelor's degree in Civil Engineering, Chiang Mai University, Thailand. He is a Research Assistant at Civil Innovation and City Engineering (CICE), Chiang Mai, Thailand. His research focuses on Sustainable Smart Campus Management and Design.

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