

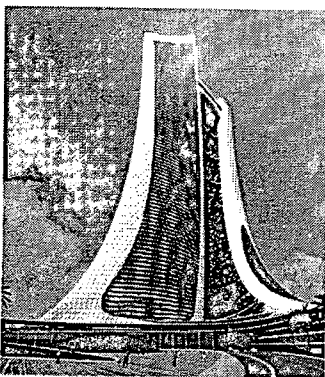
CHAPTER I

INTRODUCTION

Background and motivation

1. The idea of green building design

The idea of green building design is a current trend for the design of newly constructed buildings. It is a consequence of the energy crisis and environmental problems such as the green house effect, climate change and Global Warming. This results in the idea of sustainable development, which takes into account social, environmental and economic factors. The basis of design integrated with scientific knowledge has been used. Therefore, building science is based on passive design ideas depending on energy gained from the surrounding environment of buildings. This is to create suitable, human comfortable that will also lead to energy conservation. The technology used to build green buildings which are designed for the effective and eco-friendly use of energy, should be suitable and clean to provide building with the better operation of active design using amount of energy, especially, electricity such as air conditioning, lighting and other facility systems. Design based mostly on natural systems should be considered first before involving the use of synthesized energy.



The one of skyscrapers with integrated energy generators will be a live machine with bio-climatic walls for supporting vegetation purifying air. It has photovoltaic arrays for solar energy harnessing, rainwater and atmospheric water collection unit and will also be utilizing air flow between towers with aero generators. Self-powered Eco-Cybernetic City interacts with the surrounding environment.

Figure 1 The one of green building integrated with PV

Source: Volumatrix Group [93]

2. Energy consumption of typical buildings in Thailand

Thailand is located in a hot and humid-tropical climate, passive design techniques are necessary for the design of building envelope to prevent solar radiation, heat, humidity, thermal radiation from nearby buildings and polluted airflow circulation caused from external environment to eventually ventilate into the inside of the buildings where humans live, As the comfort zone cannot be fully controlled at all times of activities by passive techniques. Then active system has to be used to control all the previously mentioned concerns.

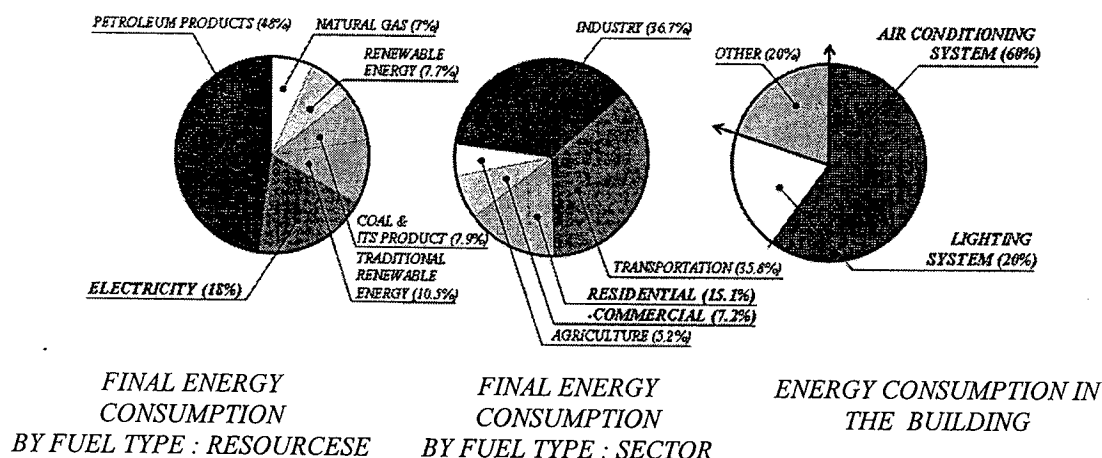


Figure 2 The ratio of energy consumption

Source: Ministry of Energy [78]

Figure 1 and Figure 2 Shows that energy consumption of typical buildings in Thailand is divided into 3 parts as follows: about 60% for air conditioning system, 20% for lighting system and 20% for other systems from the information on verification for building design according to Thai Energy Conservation Law. However, Thailand was used electricity about 17.5% came from Natural gas and traditional renewable energy and about 7.7% came from renewable energy. Some of the final energy consumption about 22.3% was used in residential and commercial sector. In 2012 Thailand's maximum peak load of electricity was about 26,430 MW [59] which was more than a year before by about 9.2%. This will trend to increase in the future.

3. Passive design integrated with clean energy

Active systems such as air conditioning system and lighting system contain ratios of energy consumption equivalent to 80% of the final energy consumption in the building. Building envelope plays an important role in solar heat gain reduction, effective prevention of heat and humidity transmission. However, all these mentioned problems need the most energy for manipulation.

Passive design is a choice for design in basic control capable of decreasing the severity of the environment surrounding the buildings. It includes designs such as shading devices, insulation and fenestration. Once all these techniques are used in combining with high quality electrical appliances and control equipment like dimmers, energy can be increasingly saved.

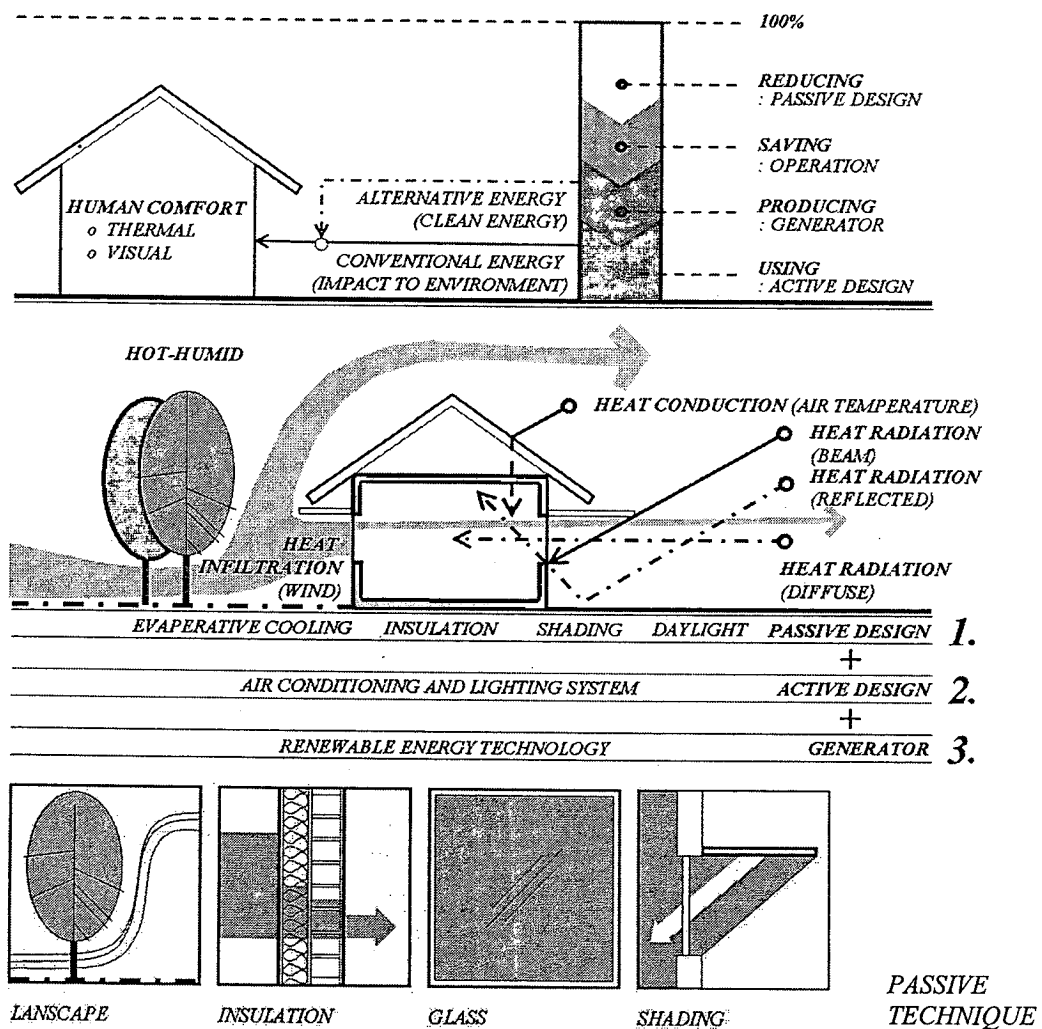


Figure 3 Integration of passive design with clean energy

Energy consumption can be decreased by using passive design techniques and then choosing appropriate, effective, well-managed technology in energy usage. Moreover, when the technology is integrated with expensive renewable energy systems using large amounts of green energy in a form of synthesizing into electrical energy processing like national grid, it will save energy and decrease the cost. However, the aforementioned integration depends on the area for installation on building envelope and the efficiency of the technology.

4. The interesting of the shading element

Concerning the energy consumption ratio of buildings in Thailand, it is seen that shading devices are one of the passive design techniques affecting heat load reduction of air conditioning system and controlling sunlight levels to save lighting system. This is to reduce the ratio of energy used.

Of course, shading devices are designed to be used with windows. It is also important to see good view clearly and exterior aesthetics. Figure 4 Shows the relation between angles and spaces affecting shape, the stand-off part of shading devices to prevent solar radiation in the period needed.

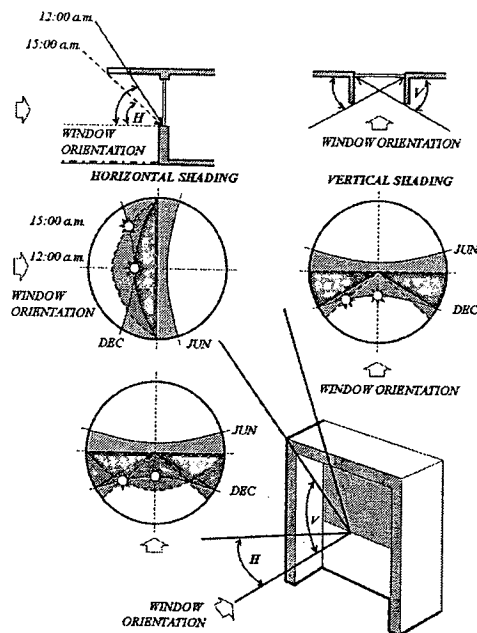


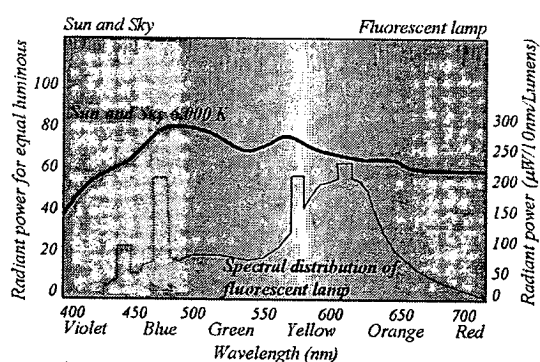
Figure 4 Angular of horizontal and vertical shading devices

Source: Moor, Fuller [25]

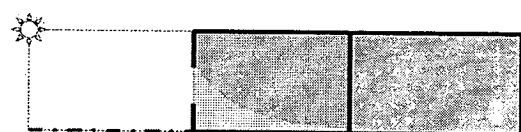
5. Advantages of view and daylight

The view surrounding the buildings is connected to the feeling and activities inside the buildings of residence. Atmosphere is being changed at all times of the day through each season for the whole year because of motion of the sun and clouds causing Karsten Harries's light phenomenon [24] stating that "...architecture, beyond providing physical frames for human activities, also interprets to human beings their place in nature and society" which means that humans need to have interaction with surrounding environment.

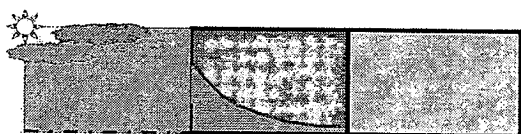
Revicki, Heerwagen and Turkish study of Alimoglu and Donmez [6, 14] concluded that "daylight significantly impacts the working hour and burnout, which be cause of stress on the job, the study is proved with nurses of Turkish. Furthermore, the color of daylight changes all time of day and seasons then it effects the human cycle time that is the reason from chemical reactions with the UV levels contained in daylights". Therefore, design must create connections with everything outside the building through the use of windows for quality of life besides receiving enough light.



The spectrum curve of electric light sources not same the sunlight spectrum, which effect biological effect not for physiological effect, because the eye can not separate the color of light spectrum only white color [14]. Furthermore, the room that using artificial light has continuously luminance all time but another room that using daylight varies the outside environment condition, which effects to human perception about the circumstance.



THE CLEAR SKY PERIOD



THE CLOUD SKY PERIOD

OUTSIDE DAYLIGHT ZONE LIGHTING ZONE

Figure 5 The comparison between electrical light and daylight

Source: Boubekri, Mohamed Daylighting [6]

6. The effect of shading devices on angles through windows

The form of the shading device affects reduction of solar heat gain including beam radiation and sky radiation. It lowers the angles of view at the same time. It can also be said that a shape of shading device is a factor determining the heat on the glass and clarity of view from the inside to the outside of the building. Figure 6 shows conditions of shapes of shading devices and angles of eyesight. In case (b), the shading device slightly outstretched is easy for a structure system, cheap and able to create clear angles. However, it cannot prevent solar radiation for the period of time when the sun goes down. In cases (a) and (c), the outstretched part of the shading device is longer than case (d), (e) and (f). Normally, shading devices are designed short due to structure, cost, law and aesthetics.

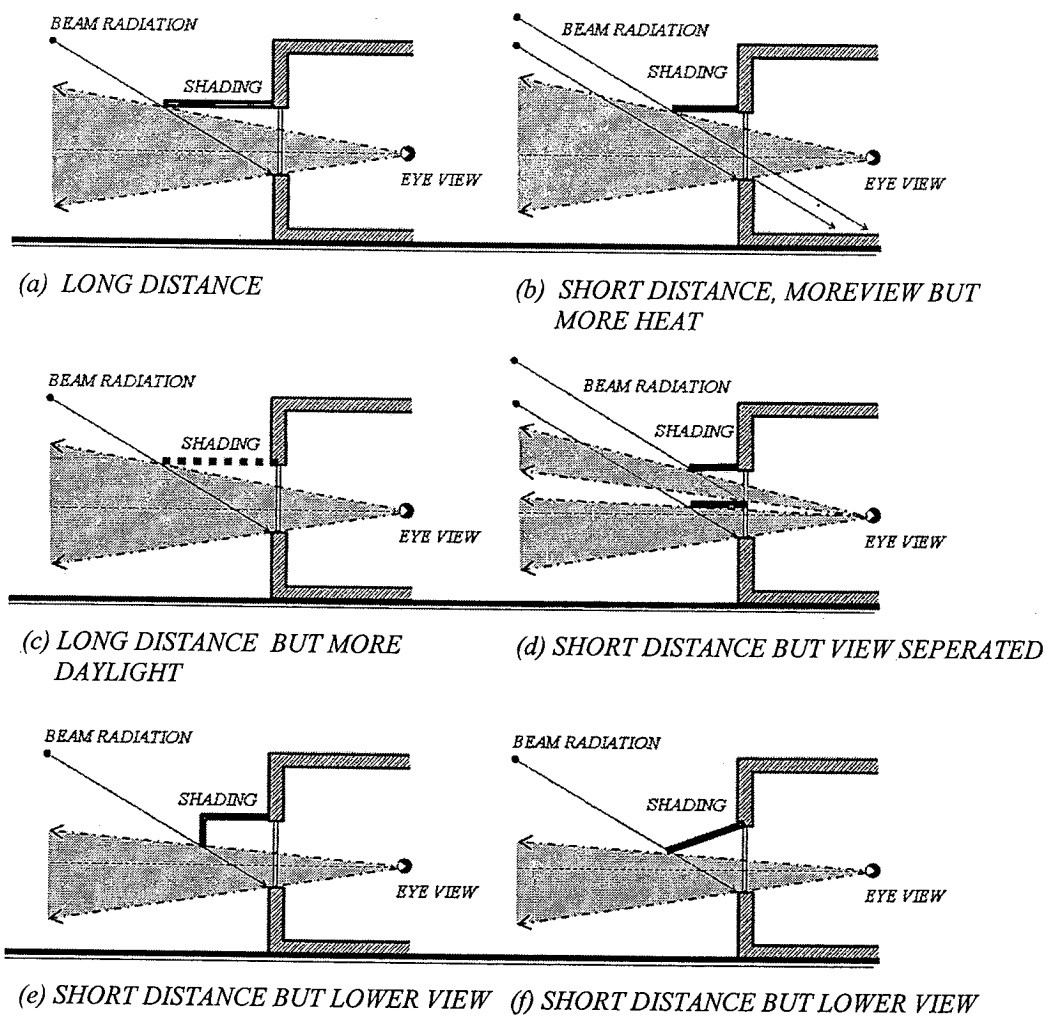


Figure 6 The relation of angle view and shading device form

7. Uncomfortable glare from sky

Daylight used to replace electrical light will shine through the windows on a plane perpendicular to eyesight looking outside. Glass is a material that lets light through it is like a light source shining directly in people's eyesight. The brighter of the sky is more uncomfortable of a glare occurs. Furthermore, windows cannot keep out direct solar radiation or sun light coming through the windows, so visibility is decreased by the disabling glare. This phenomenon, however, depends on luminance around the field of vision, apparent size of the source, direction of eye viewing and level of eye adaptation [8].

In case of a disabling glare occurs when a window receives too much luminance directly shining on the field of vision causing disability in differentiating or sight, which is the same case when perceiving the actual sun in the sky. This is one of the reasons for designing a shading device for direct solar radiation prevention. Additionally, uncomfortable glare will cause eye fatigue.

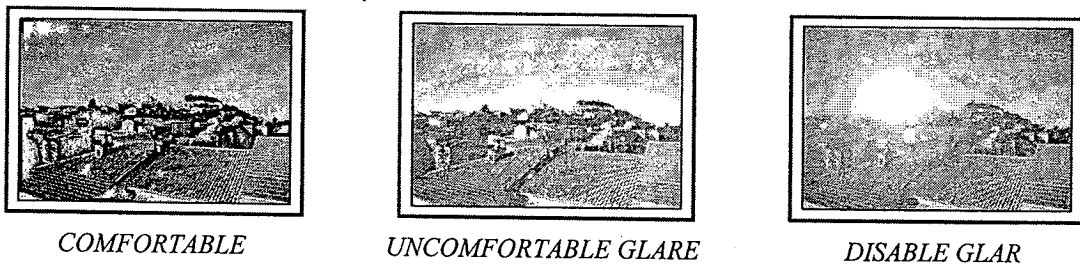


Figure 7 The glare effect from the window

8. Distance of receiving daylight from side windows

Normally, light outside the building is at 10,000-20,000 lux and about 100,000 lux when including direct solar radiation measured on the working plane in the case of a clear sky or overcast sky. However, it will decrease 30% and get lower when using a more outstretched shading device. In this case, the daylight factor can be used in estimation as the shading device causes daylight reduction in distance far from the window. This causes insufficient light for some activities in the area considered far from the window. However, at the distance very far from the window, there is no change of light in any of shading device case with different outstretched parts.

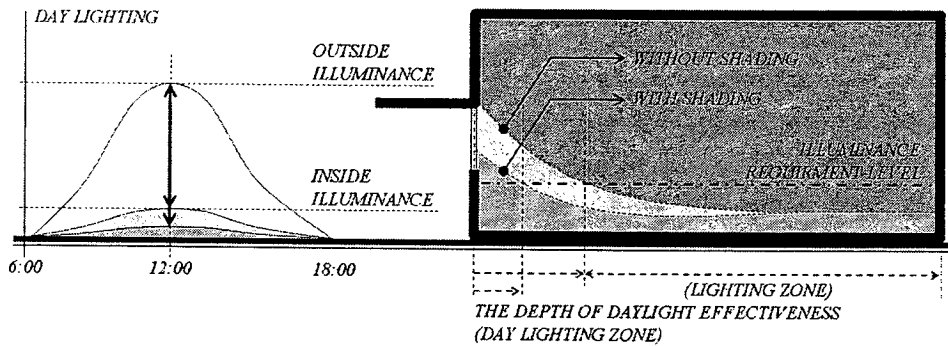


Figure 8 Effectiveness of daylight in working space

9. Building Integrated Photovoltaic system (BIPV)

Renewable energy is free, clean, eco-friendly energy generated endlessly by natural sources such as solar, wind, biomass, geothermal, hydro, wave and tidal. Photovoltaic technology is an alternative, turning energy gained from the sun into electrical energy. This technology is uncomplicated and easy to apply and manage. In case of installation on building envelope, PV module should be used instead of other exterior building materials as shown in the Figure 9.

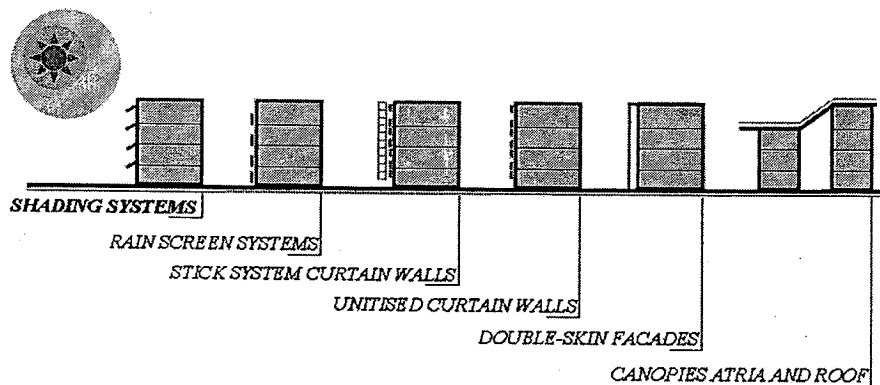


Figure 9 The building integrated PV options

Source: Simon Roberts and Nicolo Guariento [27]

In the past 10 years of studying BIPV systems, 5 aspects that need to be focused on are as follows:

Analysis of Thermal effects affecting capacity of electricity generation.

9.1 Analysis of annual energy generation compared to heat gained in case of designing semi-transparent solar cells

9.2 Analysis of energy and expenses for BIPV systems produced by using semi-transparent solar cells

9.3 Benefits, cost and increasing value for BIPV systems

9.4 Design techniques affecting electrical energy generation

Every aspect is summarized in Table 1 and the aspect of searching for installation ideas for the module on the building mostly focused on aspects of expenses and usability of semi-transparent solar cells.

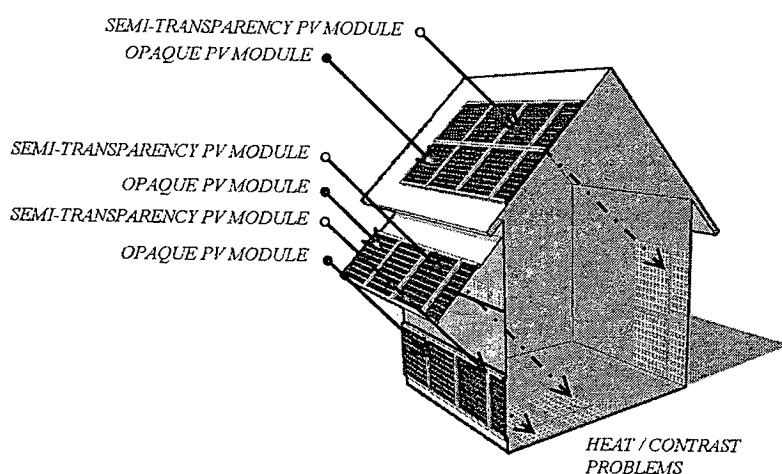
Table 1 The aspects from international paper since 1999 (10 years)

Problem of studies	Sample of papers
The effect of PV working	
1. Thermal effect of PV efficiency	[43]
2. PV ventilated of PV module	[40], [45]
3. Heat and power output of PV system	[39], [42], [51]
4. Cost and benefit of PV system	[38], [39], [41], [46], [47], [49]
The effect of PV design	
1. Semi-transparent PV module	[43]
(window, wall, skylight, roof)	[38], [39], [42], [46], [49], [51]
2. PV facades Ventilated	[40], [45]
3. Concentrating of PV module	[50]
4. Shading integrated PV module	[44]

10. Advantages and disadvantages of BIPV options.

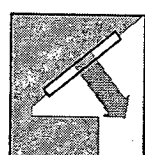
BIPV options were presented in the form of building envelope such as wall panel, roof, side/top light and shading. In the case of a tropical building, solar heat gain shining through window or glass, which is also called transparent material letting heat in through both conduction and radiation, should be avoided. It is better to use insulating material and prevent solar radiation by using a shading device.

However, as PV module is not considered insulation, it should not be installed instead of vertical plane glass despite that there is a usable type because of its transparency. This is also because it is the worst angle for receiving solar radiation. As for installing it as a roofing material, it still needs to add more layers of heat insulators the same way wallpaper being used. Unlike shading devices, there is no need for insulation because its angle can be adjusted according to appropriateness, and it provides benefits in terms of heat prevention module and light control for both air conditioning systems and lighting systems consuming most of the energy in the building.



ELEMENT OF BUILDING

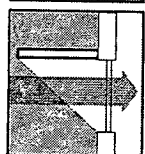
CONDITION OF MODULE INSTALLATION



ROOF

- > Good for generating power
- > Good/poor for protecting heat gain
- > Good/Poor for daylight

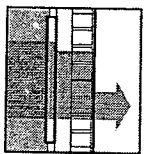
- : direction and slope
- : Insulation and ventilation back side
- : Semi-transparency



SHADING

- > Fair for generating power
- > Good for protecting heat gain
- > fair for daylight

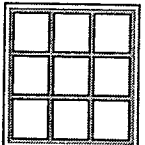
- : direction and slope
- : Shading distance and direction
- : Shading distance and direction



WALL

- > Poor for generating power
- > Good/poor for protecting heat gain
- > Poor for daylight

- : direction and slope
- : Insulation and ventilation back side
- : Semi-transparency



SEMI-TRANSPARENCY

- > Good/Poor for generating power
- > Poor for protecting heat gain
- > Good for daylight

- : Element of building
- : direction and slope
- : direction and slope

Figure 10 BIPV options for the tropical building design

11. The reduction of solar radiation on solar module plane

Solar modules installed on a vertical plane such as building wall (like the case of a shading device, or SIPV, under half sky according to Figure 11) diffuse sky radiation divided into 2 parts by shading of the building's vertical plane. The plane is a blocker of direct solar radiation for the period of time when the sun is behind the shading device. Solar radiation reflected with a wall plane above solar module will be more or less depending on reflectance of the reflector, which is different from installation on a flat plane without any covering.

Therefore, SIPV receives total solar radiation falling down against the solar module from beam radiation, half sky radiation, ground reflected radiation and building reflected radiation. This is due to the problem of shade effect from the building, which affects decreasing in electric current production. Therefore, SIPV contains problem of decreasing solar radiation caused by building itself.

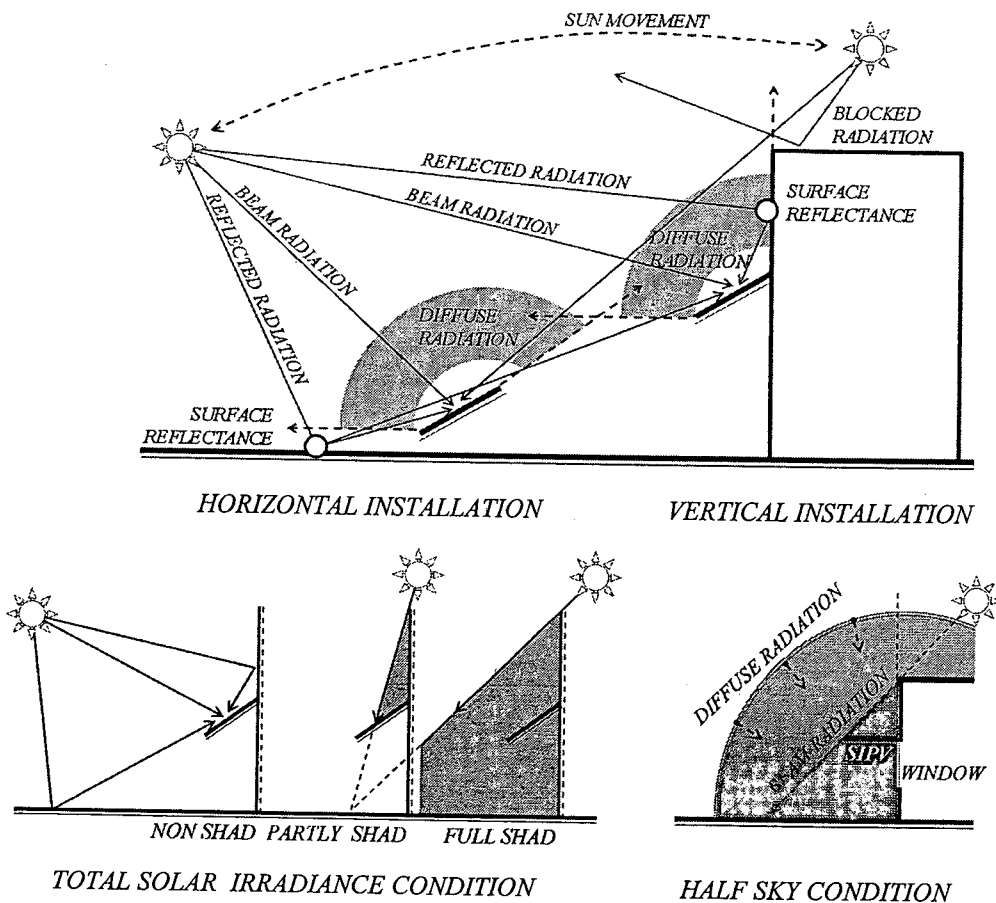
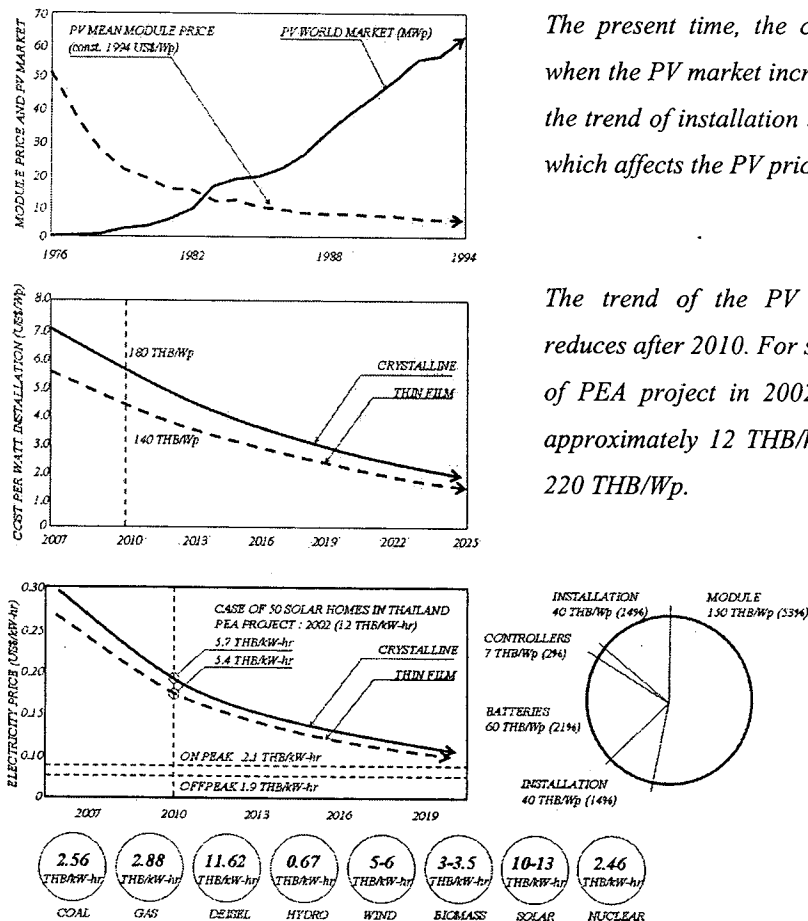


Figure 11 The effect of vertical installation

12. The investment of Photovoltaic system

The BIPV system is one type of building material capable of producing energy. The amount of produced energy depends on the amount of total solar radiation falling down on skin of the solar cells and area supporting solar radiation (both direct and diffused solar radiation). In the case of SIPV limited conditions than is the case on the roof unobstructed because it is material that depends on efficiency of electricity production and area of installation on the building. Plus, solar module is more expensive when compared to other materials or energy production technology, wind turbine technology, biomass technology and hydro turbine technology etc. as shown in Figure 12 below.



The present time, the cost decreases contentiously when the PV market increases contentiously too. And the trend of installation in the future is still increase, which affects the PV price as well.

The trend of the PV technology cost gradually reduces after 2010. For solar home system, 50 homes of PEA project in 2002 estimates the energy cost approximately 12 THB/kW-hr and the price is 190-220 THB/Wp.

Figure 12 The PV pricing trends and electrical prices

Source: V. Napatra [35]; Banmuang [59]; John Schmitz [70]; Martin LaMonica [75]; Michael S. Davies [77]; United Nations University [91]

In 2010, price of crystalline silicon technology is higher than thin film technology's at about 180 THB/W_p and 140 THB/W_p respectively. Although photovoltaic technology results in cheap electricity bill of 5.4-5.7 THB/kWh and ratio of solar module price is at 53% of system price referred from example of investment to install in solar home project, BIPV provides more benefit than just produce electrical energy such as decreasing expenses of building envelope material, structure without using area to install. Especially, in case of SIPV which can reduce the use of energy in air conditioning system and lighting system. Therefore, it is considered an interesting advantage when comparing to disadvantages of producing process.

Conclusion of problems for research

SIPV is appliance for clean energy production, heat prevention and light control designed to use with windows in the condition of comfort zone regarding temperature and light and discerning out the window. The problems are as follows:

1. SIPV prevents heat from solar radiation coming into windows. However, it decreases a chance to receive daylight and perceive view outside the window.

2. SIPV cuts out some part of solar radiation due to installation on vertical plane with building as sunshade blocking solar radiation from getting in.

3. SIPV is producing electricity energy. However, it is still an expensive technology.

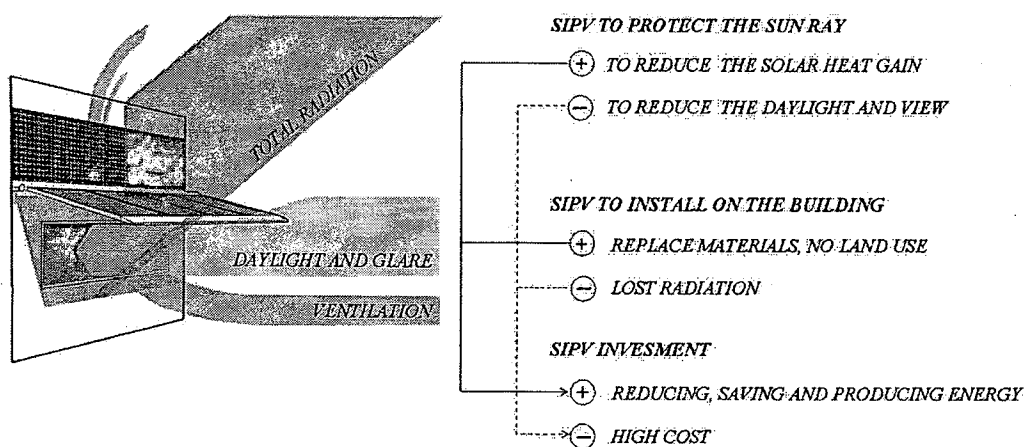


Figure 13 Advantages and disadvantages of SIPV

Conceptual design for problem solving

SIVP design aims to optimize installation to save total energy of building. The concepts are as follows:

1. To prevent direct solar radiation and part of diffuse radiation from half sky radiation
2. To adjust level of daylight shining in through the window to make most angles and least glare
3. To find direction, inclined angle and suitable installation to be able to produce most of energy from operation of solar module

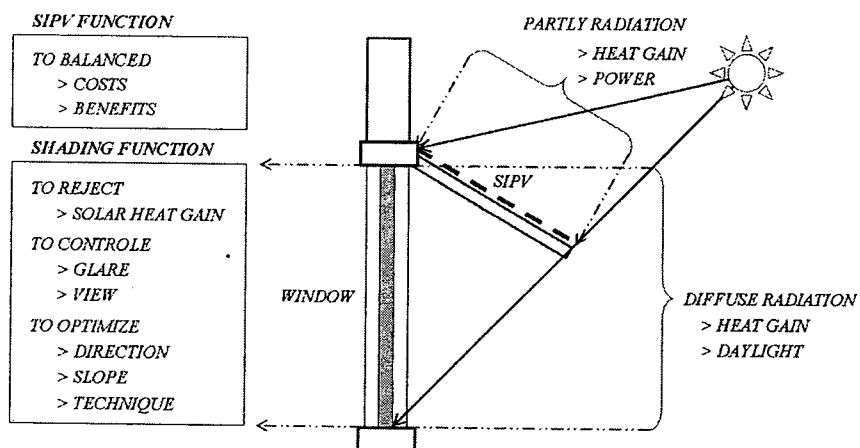


Figure 14 Integrative functions of SIPV

Purpose of research

1. To optimize shading to decrease heat gain and increase daylight usability of shading device integrated photovoltaic system
2. To optimize costs and benefits of shading device integrated photovoltaic system

Hypothesis

Shading device integrated photovoltaic system helps in reducing cooling load of air conditioning system and make a use of daylight to save energy from lighting load including creating a clear angle of buildings in Thailand.

Conceptual framework

This research focuses on designing shading device integrated photovoltaic system containing 4 steps as shown in Figure 15

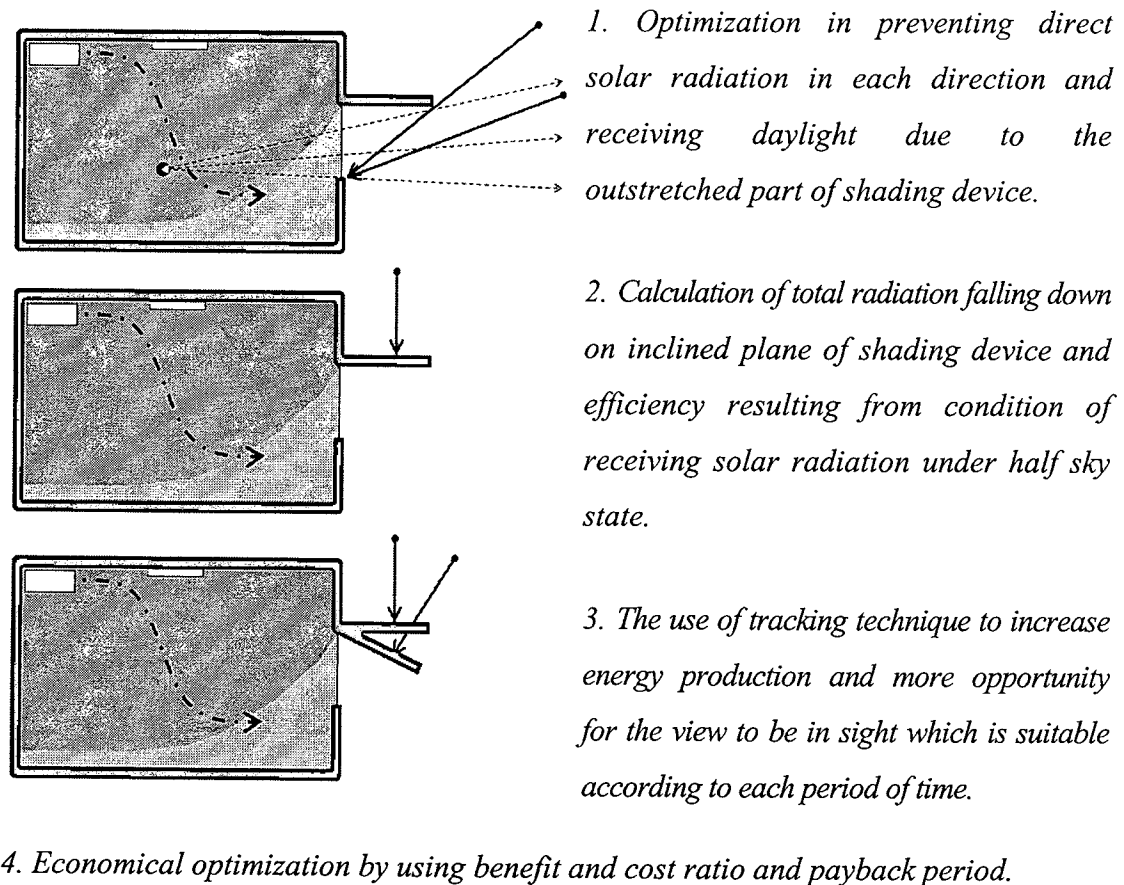


Figure 15 4 steps of frame work

Research conditions

If it is for study experiment and analysis, there are 4 conditions as follows:

1. Design for Latitude of Thailand
2. Studying from models installed at SERT, Naresuan University, Pisanulok and Faculty of Architecture, Chiang Mai University, Chiang Mai, Thailand
3. Case study and data collection are the use of the solar module of amorphous silicon and poly crystalline silicon technologies belonged to SERT, Naresuan University, Pisanulok
4. Economic optimization from direct and indirect analysis

Benefits of research

Benefits of this research occurred from the idea of green building are as follows:

1. Building system can save the total energy of building by using shading device integrated photovoltaic system
2. The clear angle of windows comes from the design of shading device integrated photovoltaic system
3. The investment in shading device integrated photovoltaic system is worth and can receive payback in a short period of time

Key words

Key words for this research are such as

1. SIPV is Shading Device Integrated Photovoltaic System
2. Working space is room for general activities and 3.0 meters height measured from the floor to ceiling
3. Comfort space is room that dry air circulate and relative humidity are controlled at 25 °C and 55% RH respectively. Appropriate air conditioning system and lighting at the working plane is 300 lux minimum receiving artificial light and daylight coming through the window

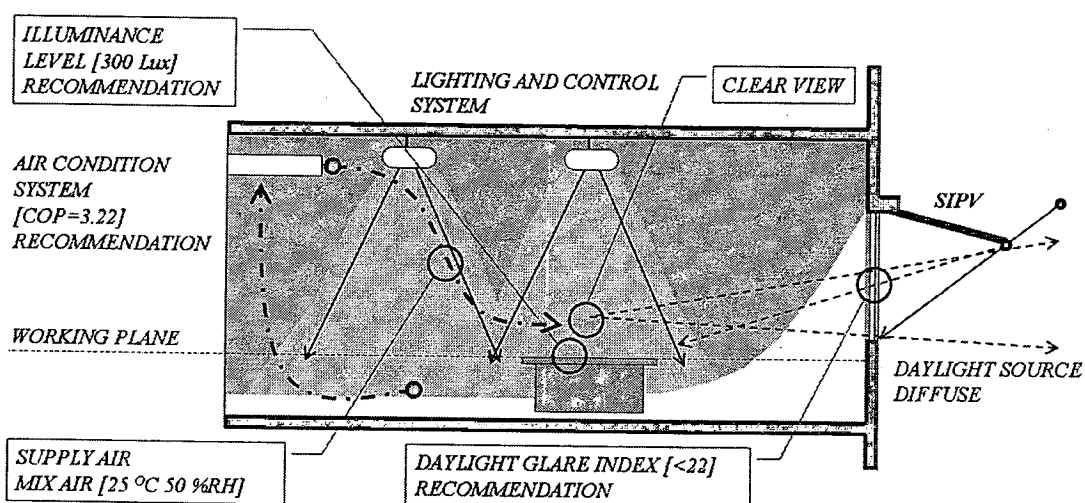


Figure 16 Key words of study design