공학석사 학위논문

Economic Feasibility of Integration of Renewable Energy for Public Buildings in Vietnam

베트남의 공공 건물에 대한

신 재생 에너지 통합의 경제적 타당성

2014 년 7 월

서울대학교 대학원

기계항공공학부

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이 논문을 공학석사학 위논문으로 제출함

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Nguyen Tien Thinh 의 석사 학위논문을 인준함

2014 년 7 월

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Abstract

Economic Feasibility of Integration of Renewable Energy for Public Buildings in Vietnam

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Vietnam has been said to have a large potential or renewable energy, but the current use of those resources is still limited. High cost and shortage of effective promotion policies are the issues that make renewable less attractive. In this study, the authors investigated the economic feasibility of using renewable energy in public buildings in the country, concerning two energy resources: solar power and biomass. To do that, cost-effective method developed by Oh et al. [15] was used to analyze integration of renewable energy solutions into the energy supply systems of a hotel and an office building in Ho Chi Minh, Vietnam. Specifically, the economic feasibility for the two buildings to use renewable energy was studied. Based on the results, the authors suggested a subsidy plan which helps promote the use of renewable energy in those types of buildings.

Keywords: Solar Water heater; Solar Photovoltaic; Biomass; Energy Demand Pattern; Energy Policy; Net Present Value

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Nomenclature

NPV	= Net present value
CRF	= Capital recovery factor
$\boldsymbol{C_i}$	= Initial cost
$\emptyset$	= Maintenance factor
$\boldsymbol{C_o}$	= Unit cost of energy by current energy supply configuration (VND/kWh)
$\boldsymbol{C_{RE}}$	= Unit cost of energy by new energy supply configuration (VND/kWh)
$\boldsymbol{E}$	= Total energy produced in a year (kWh)

Abbreviation

Solar PV	= Solar photovoltaic
SWH	= Solar water heater
BB	= Biomass boiler
RE	= Renewable energy

Currency exchange rate

1USD = 21000VND

Chapter 1. Introduction

1.1. Problem statement

Lying in the tropical region of Pacific Ocean with a long coast, Vietnam has a large potential for renewable energy. Even though, due to its limitation in technology and effective policies, the use of these energy sources is still at low level. Renewable energy potential for electricity and heat and the current use has been summarized by Cuong [1], as shown in Table 1.1. In the attempts to reach a certain percentage of renewable energy production over total energy demand of the country, which is 4.5% by 2020 and 6% by 2030 [3], a few promotion programs for extending the use of solar water heater and solar photovoltaic in residential and public buildings has been implemented by the government but not yet show their expected outcomes. [2]

RE Sources	Small Hydro (<30MW)	Biomass	Biogas	Solar Energy
Potential	>7000MW	>2500MW	>100MW	4-5kwh/m^2/day
Use	600MW	150MW	0.5MW	2MW

RE Sources	Wind Energy	Geothermal	Solid wastes	Ocean Energy
Potential	1750MW	340MW	>320MW	100-200MW
Use	37.5MW	0	2.4MW	0

(a) For electricity generation

RE Sources	Solar	Biomass	Biogas
Potential	>10000KTOE	>20,000KTOE	400KTOE
Use	0.86KTOE	13,513KTOE	80KTOE

(b) For heat generation

Table 1.1. Renewable energy potential generation and current use in Vietnam.

1.2. Previous research

One of the first research efforts on the issue had been done by Nguyen & Pryor, 1998, which investigated the feasibility of solar water heaters, showing a saving of energy cost and an average payback period of three years for commercial buildings. In 2012, Leinonen & Cuong [6] studied the development of biomass fuel chain in Vietnam. According to the results, providing heat by industrial boilers using rice husk and wood pellets is 60% lower than using electricity. Besides, the integration of solar photovoltaic into public buildings was analyzed by Khanh [7]. According to the author, solar photovoltaic is most technically feasible for large buildings in the south of the country, where the average solar radiation intensity is highest and stable all year round. Qualitatively, these researches show a possibility of economic benefit by installing renewable energy for public buildings in the country.

Despite of those efforts, there has not been any quantitative method to evaluate the economic feasibility of integration of different renewable energy options into public buildings in Vietnam. Recently, in a study by Oh et al. [15], the authors have developed an analytical tool to do the task, in which the energy demand patterns of a building is the key for analysis. This cost-effective method has been validated for public buildings in South Korea, opening a possibility to use as a quantitative approach for renewable integration in Vietnamese buildings.

1.3. Research objectives

In this research, the authors used this approach to investigate the economic feasibility of using the three renewable energy solutions: solar PV, solar water heater and biomass boiler for public buildings in the country, given the current cost and climate conditions. Then, a suggestion on renewable energy policy is introduced to help promote the use of renewable energy.

Chapter 2. Current cost of renewable energy for urban use

Three renewable energy options which are suitable for public buildings are discussed in this section: solar photovoltaic, solar water heater and biomass (rice husk and wood pellet). Considering the legal frame assisting the development of renewable equipment supply chain, the government has issued three fundamental policies: Decision 130/2007-QD-TTg, 2007, 218/2013/ NĐ-CP, Law on Efficient and Effective Energy Usage, 2010 [4]. Those policies bring the following incentives for renewable energy manufacturers: i. Advantages on land use and capital for renewable projects; ii. Free import tax on fundamental renewable equipment & materials; iii. Income tax at 10% for enterprises manufacturing renewable products, compared to 22% of other sectors (2014). These promotion have encouraged domestic enterprises and research institutes to bring the price of solar water heater down to the average 3.5 million VND (~167USD) per m2 panel area and that of solar photovoltaic to 70 million VND (~3400USD) per m2 panel area. On the other hand, being an agriculture country helps local suppliers to offer biomass fuel at competitive price: 2.5 million VND (~125USD) per ton of wood pellets with net calorific value of 4500kcal/kg and less than 2% ash, which is suitable for urban building using low emission biomass water boilers. The data were collected from domestic manufacturers and merchants in 2013 and 2014[18].

Chapter 3. Cost-effective integration method

3.1. Evaluation method of economic feasibility

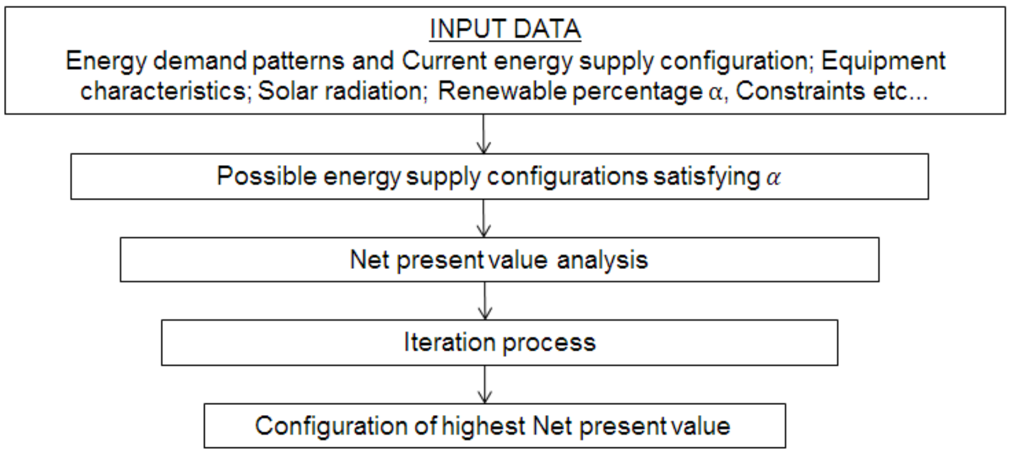


Figure 3.1. Analysis flow chart

In this study, the economic feasibility of renewable energy integration for buildings was investigated over a range of the percentage of energy supplied by renewable solutions α, which is defined as:

$$\alpha = \frac{Annual\ energy\ supplied\ by\ renewable\ solutions}{Annual\ energy\ demand\ of\ the\ building}$$

The net present value concept was used as the economic feasibility indicator, according to Thumann [20] and Oliveira et al [21]. A positive net present value indicate a feasible integration and inversely, a negative net present value implies that the cost of energy using renewable energy solution is higher than current energy supply system. The calculation of the net present value will be discussed in the next session.

At first, the input data including energy demand patterns, climate conditions and renewable equipment data were obtained for the research site, which is Ho Chi Minh, south of Vietnam. Given the input data, all possible energy supply configurations which satisfy α are figured out. In the next step, the net present value of each configuration is calculated and finally, an iteration process was done to pick out the configuration which brings the highest net present value (Figure 3.2). More specifically, the output is the best cost-effective scheme to integrate renewable energy into a building.

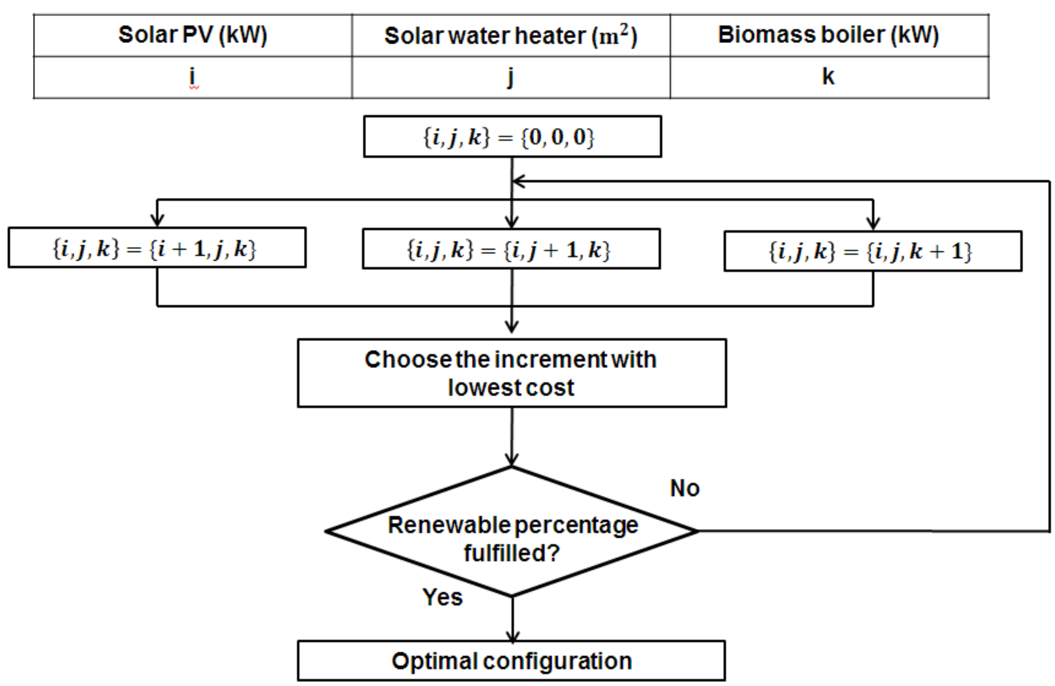


Figure 3.2. Iteration process.

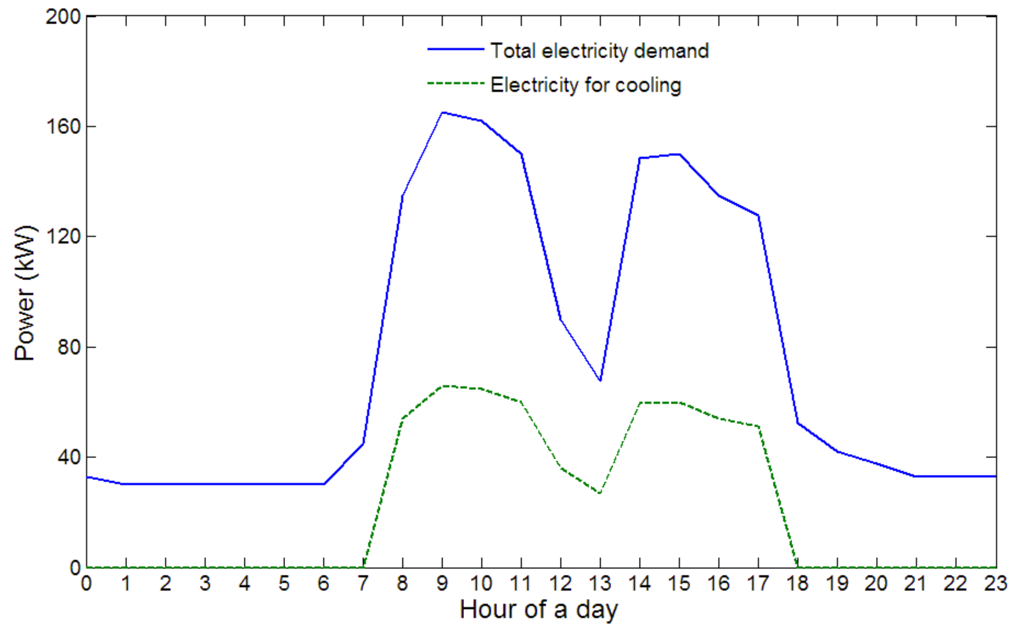
3.2. Estimation of energy demand patterns

In this study, two buildings of hotel and office types, both located in Ho Chi Minh, Vietnam were investigated. For the office building, the hot water demand is negligible [10] so that only electric demand and cooling demand are considered. 24 hour electric demand data was obtained on a typical day in July, 2013. Since the measurement of electricity for cooling is not able to record for this building, only total electric demand pattern was obtained. Then the electric demand for air cooling purpose was estimated by 40% of total electric demand during working hours, according to Kong et al. [11] (Figure 3.3a). Similarly, the estimation for the year round energy demand was made, assuming:

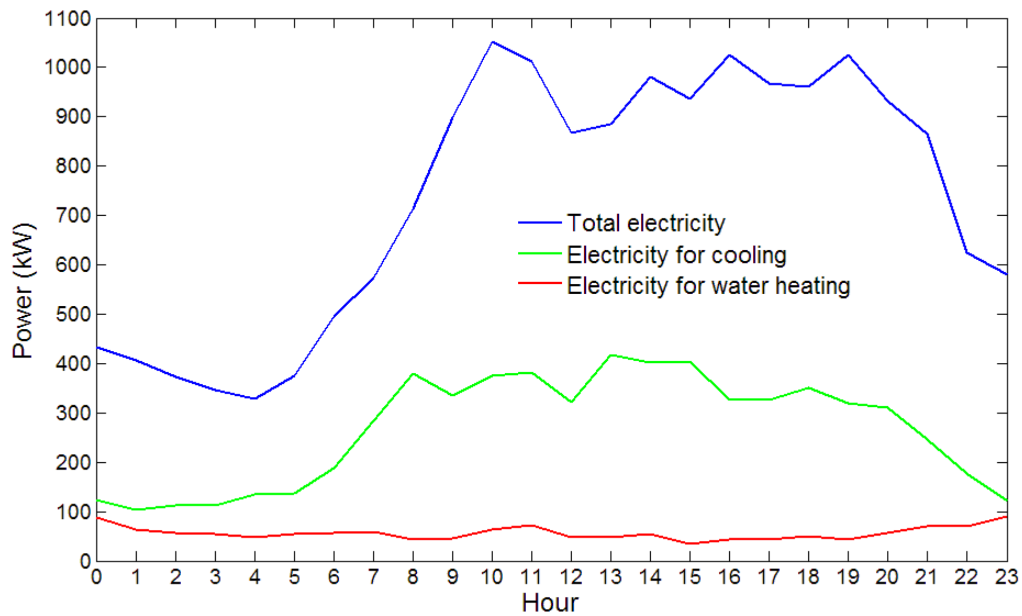
i. The demand pattern for everyday of each month is identical.
ii. The heat demand for an office building, which is hot water demand, is neglected.
iii. The pure electric demand, not including electricity for air cooling, is assumed to stay constant throughout a year. The electric demand for air cooling is estimated by the outdoor temperature. (Figure 3.4)

Detail estimation process is shown in Appendix i.

The estimated energy demand patterns of the office for a year is described in Figure 3.5.



(a) An office building on a typical day in July, 2013.



(b) A hotel on a typical day in November, 2012.

Figure 3.3. Electricity demand patterns

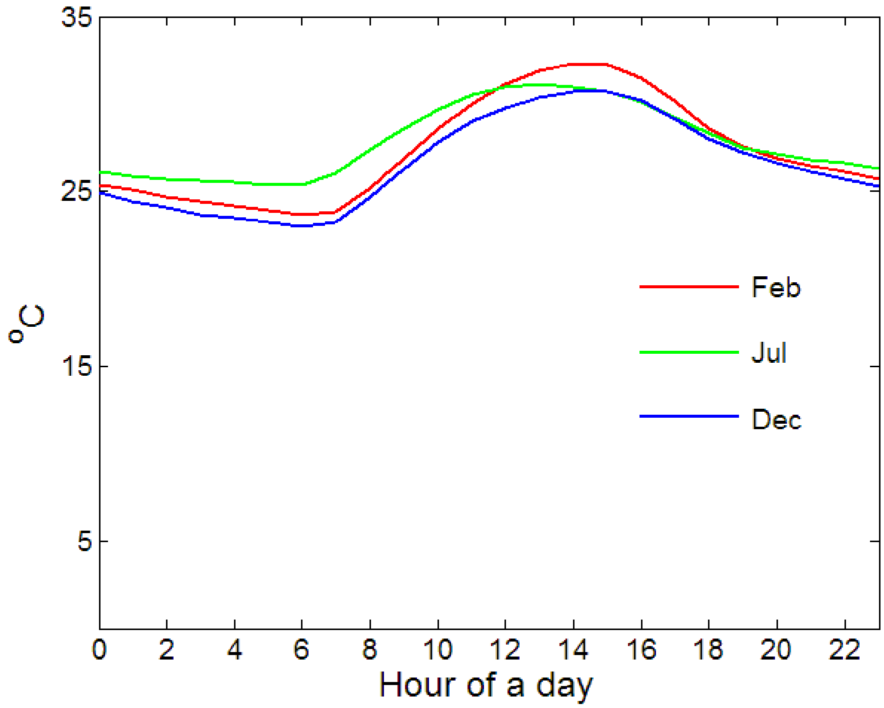
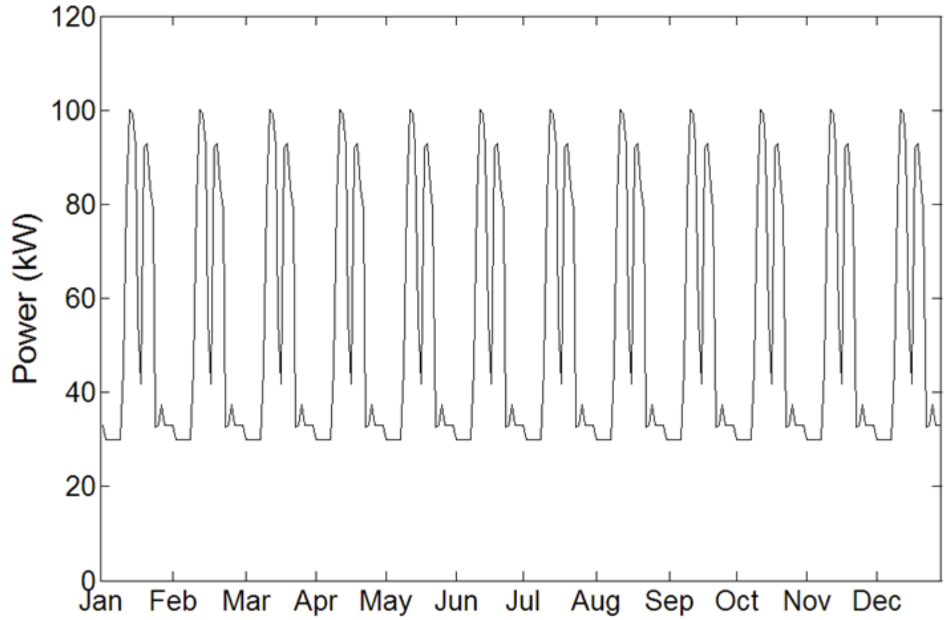
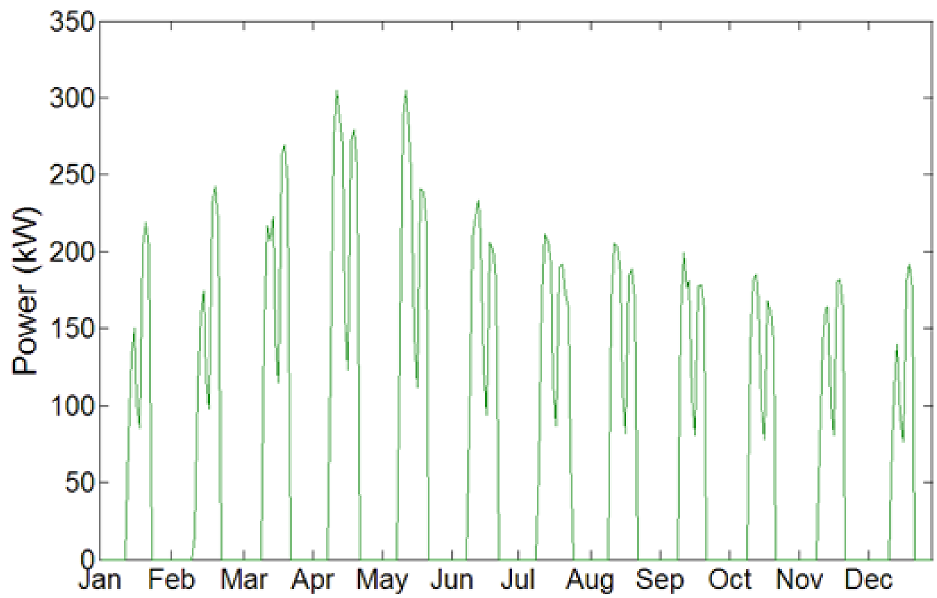


Figure 3.4 Daily temperature in Ho Chi Minh, Vietnam, 2009.[17]



(a) Electric demand



(b) Cooling energy demand

Figure 3.5. Energy demand patterns of the office building.

For the hotel, energy is used for three purposes: air cooling, water heating and electric appliances (elevator, lighting, etc…) [12]. Hence, electric demand for cooling, water heating and other electric appliance were measured separately on a typical day in November, 2012 (Figure 2a). Then the 8760 hours or year round energy demand patterns are estimated with the following assumptions:

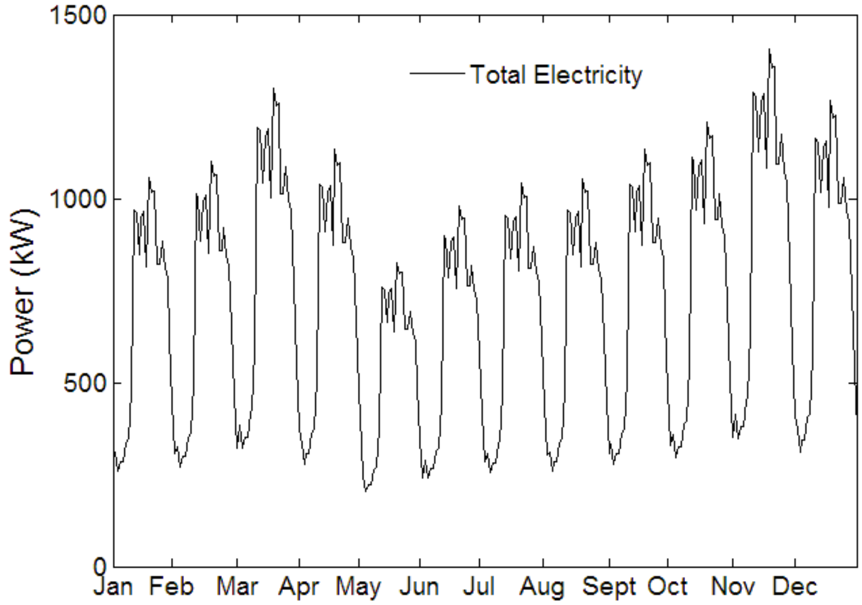
i. The demand pattern for everyday of each month is identical.
ii. Total electric demand of each month is proportional to the total electricity consumption of that month (Table 3.1).
iii. Cooling energy demand and water heating energy demand of each month are proportional to the monthly occupancy rate.

Detail estimation process is shown in Appendix ii.

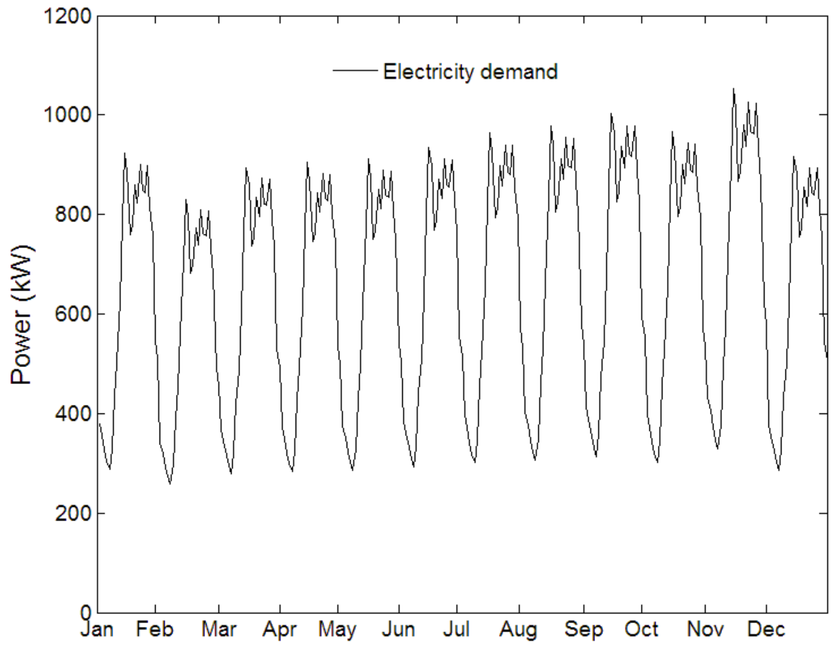
The estimated energy demand patterns of the office for a year is described in Figure 3.6.

Month	Electricity Consumption (kWh)	Occupancy Rate (%)
Jan	664,822	69
Feb	597,025	72
Mar	644,111	85
Apr	651,712	74
May	656,939	54
Jun	673,080	64
Jul	694,090	68
Aug	704,693	68.9
Sep	722,922	74
Oct	696,387	79
Nov	757,917	91.8
Dec	660,634	82.7

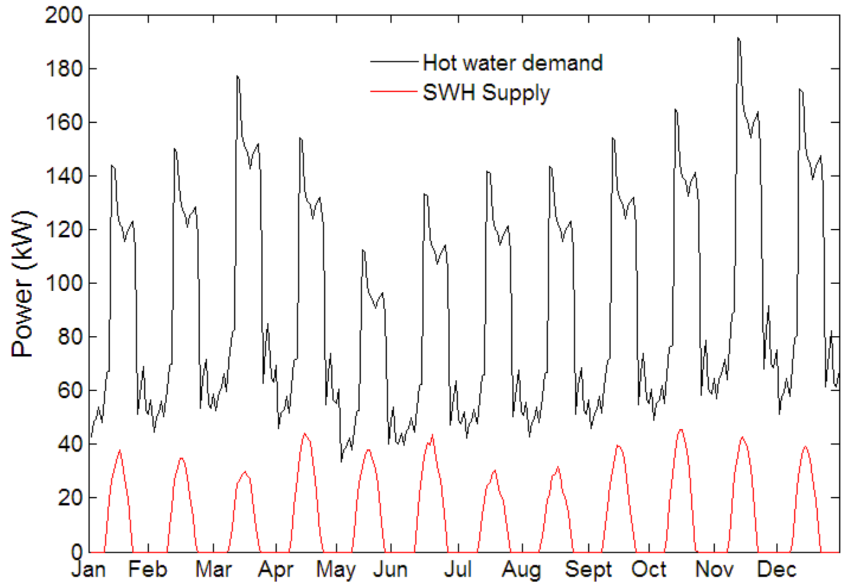
Table 3.1. Monthly electricity consumption and occupancy rate of the hotel.



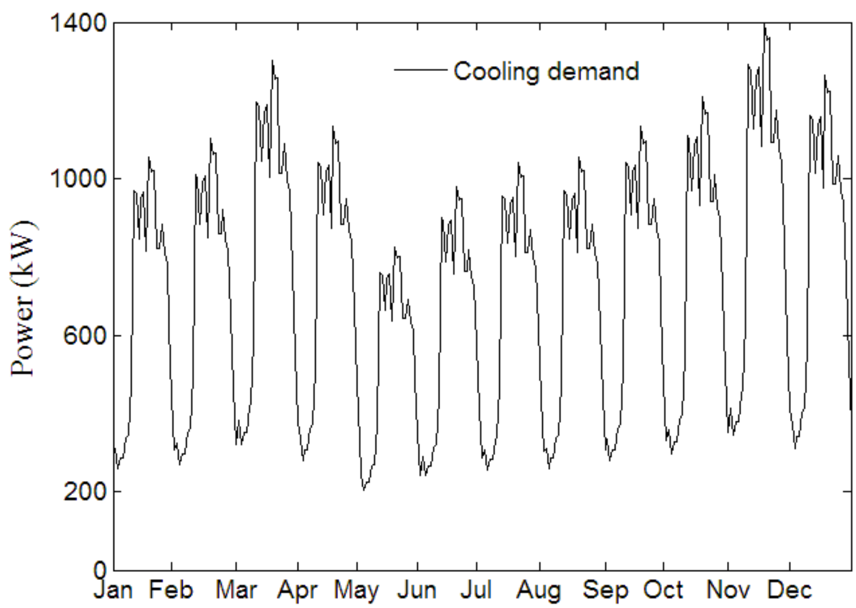
(a) Total electricity demand



(b) Electricity demand without cooling and heating



(c) Heat demand for water heating and supply by current solar water heater system



(d) Cooling energy demand

Figure 3.6. Energy demand patterns of the hotel.

3.3. Estimation of solar radiation on photovoltaic panel surface

The performance of both solar photovoltaic and solar water heater heavily depends on the solar radiation intensity on its inclined surface. According to Oh et al. [16] and Loutzenhiser et al. [20], hourly solar radiation on an inclined surface can be estimated accurately from monthly clearness index. In this research, the author adopted that estimation, with the clearness index (*K*) calculated as follow:

$$\boldsymbol{K = \frac{Direct\ radiation\ intensity(W/m^2)}{Extraterrestial\ radiation\ intensity(W/m^2)}}$$

Monthly solar radiation data for Ho Chi Minh in 2009 is provided in Table 3. According to that, *K* varies from the minimum 0.37 in February to the maximum 0.62 in August and the average value is 0.49. The value of clearness index indicates the state of the atmosphere. The higher value of *K* implies a more clear sky and the earth surface receives more direct sunlight energy. Meanwhile, the low value of *K* indicates a cloudy sky, partly blocking the earth surface to receive solar energy.

Month	Extraterrestrial radiation (W/m^2)	Direct radiation (W/m^2)
Jan	5600	2184
Feb	6605	2436
Mar	6616	2505
Apr	6620	2919
May	5561	2783
Jun	5438	3211
Jul	5190	2754
Aug	5361	3323
Sep	5215	2977
Oct	5180	2848
Nov	4993	2491
Dec	5161	2477

Table 3.2 Monthly solar radiation data, Ho Chi Minh 2009.[17]

3.4. Calculation of net present value and iteration process for optimal energy supply configuration

In this research, net present value concept was used as an indicator for the feasibility of renewable energy integration schemes. Firstly, the capital recovery factor (CRF), which is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time, given the discount rate $\mathrm{i} = 4.5\%$ according to the State bank of Vietnam and a time period $\mathrm{n} = 20$ years, was calculated [22].

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

The present value of the cost to supply energy demand of the building in 20 years by the renewable solutions was compared to that by current energy supply system. Net present value is formulated as below [22]:

$$NPV = \frac{C_o - C_{RE}}{CRF}$$

Where C_0 is the cost to supply annual energy demand by current energy supply configuration of the building and C_{RE} is that cost by the new energy supply configuration with renewable energy integrated.

If $C_{RE} > C_0$, the cost to feed the energy demand with new configuration is higher than the current configuration, resulting in a negative net present value, which means the integration is economically unfeasible. In case $C_{RE} < C_0$, obviously, it is economically benefit for the building to integrate renewable solutions for its energy demand. Hence, the integration is feasible.

The comparison between the unit cost of heat and electricity supplied by different sources are described in Table 3.3 and Figure 3.7. Accordingly, the unit cost of electricity supplied by solar PV is always higher than the electric grid, hence a building has to pay more to use renewable energy when they install solar PV to supply electric demand. On the other hand, the cost of heat for hot water supplied by solar water heater and biomass solutions are much lower than that by Electric boilers. This difference results in a saving of money when a building replaces electric boilers by those two renewable solutions to supply its heat demand for water heating. In this investigation, an iteration method to integrate the most cost-effective renewable energy solutions to supply the energy demand of a building is developed.

Electric boiler	2100VND/kWh
Solar water heater	840VND/kWh
Biomass boiler/ Wood pellet	920VND/kWh

Table 3.3. Heat cost by sources

The smallest size of each renewable energy source is 1kW for solar PV, 1m^2 of panel area for solar water heater and 1kW for biomass boiler. Firstly, the indices {i,j,k} characterize the capacity of each renewable source is set to be all 0 (Figure 3.2). Then a comparison of NPV by increasing each element by 1 unit is done to figure out the increment with highest NPV, which means the lowest cost. The process is repeated until the percentage of renewable energy supply is fulfilled. The final set of indices {i,j,k} satisfying the percentage α is the renewable energy configuration with highest NPV, hence the optimal configuration.

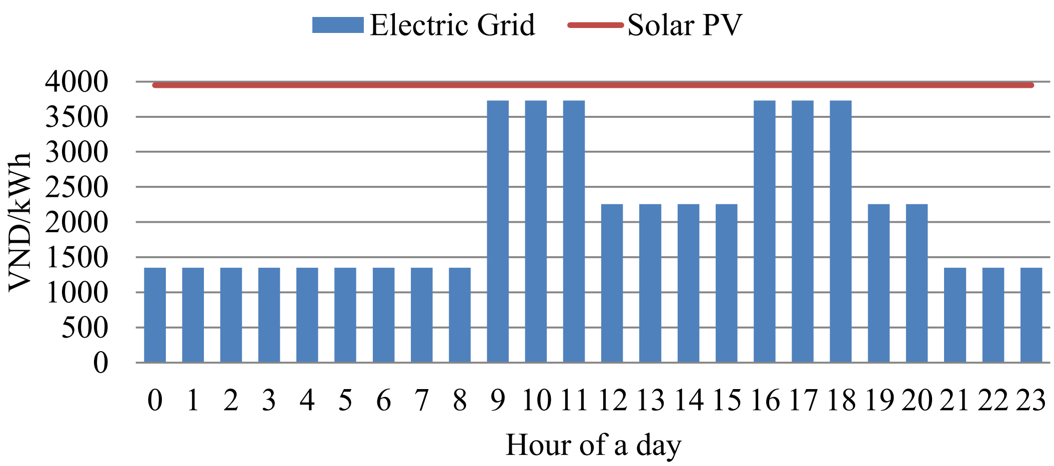
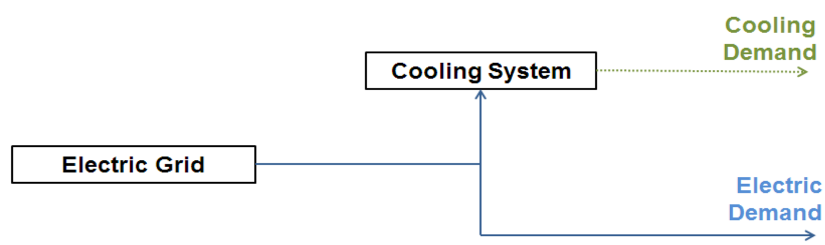


Figure 3.7. Electricity cost by sources

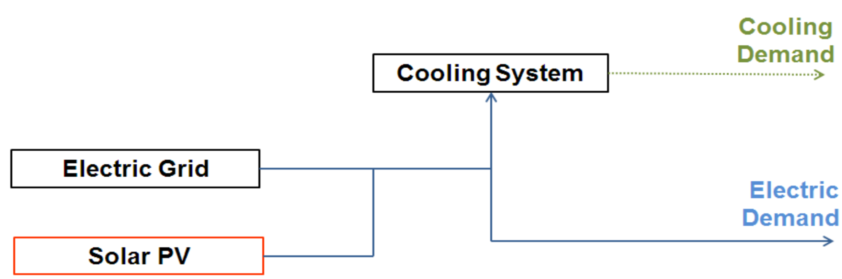
Chapter 4.Results

4.1. Integration of renewable energy into an office building

Regarding the technical feasibility of integration, because the office building demands only electricity, only solar PV can be integrated to supply electricity [14]. The total area limit for solar PV panel is 600m2. The current and renewable-energy-integrated energy supply configurations of the office building are described in Figure 4.1a. & 4.1b. The cooling demand and electric demand are fed completely from the electric grid under the current configuration. Under the new energy supply configuration, the electricity is partly supplied by solar PV.



(a) Current energy system configuration



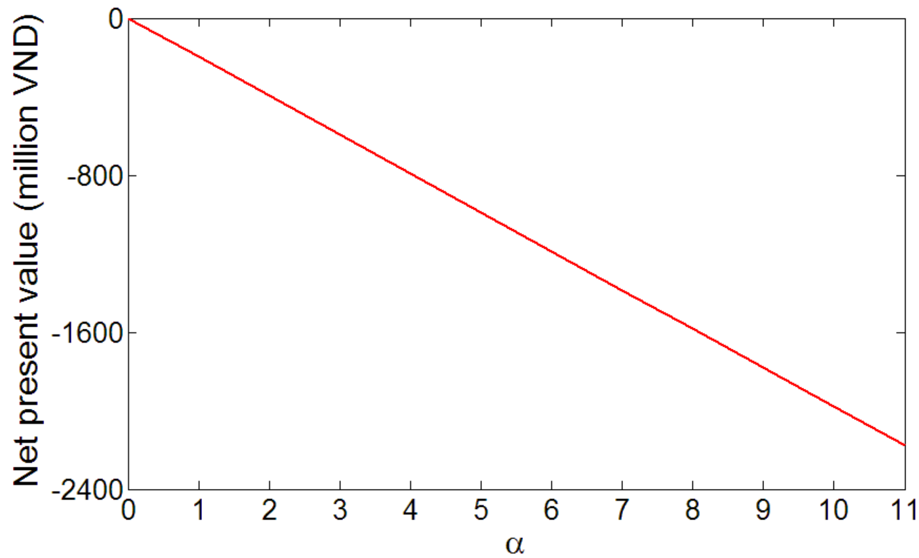
(b) New energy system configuration

Figure 4.1. Current and new energy supply configuration (Office building)

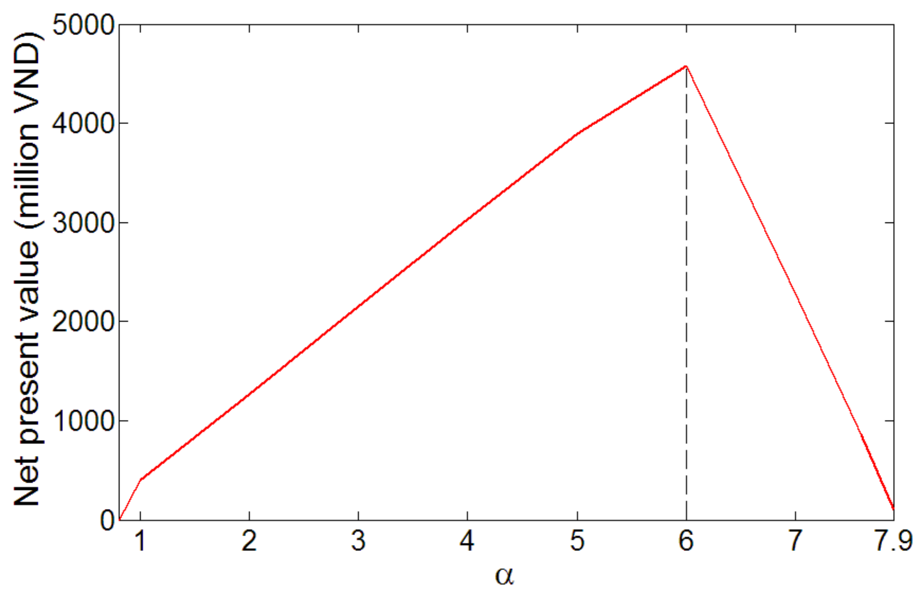
The net present value variation under different percentage of renewable energy supply is shown in Table 4.1 and Figure 4.2.a. Because the electric production cost of solar photovoltaic is higher than the average electric tariff (Figure 10), the net present value is always negative as more solar PV is integrated into the supply system. This negative trend of NPV indicates the economic unfeasibility of using renewable solution for this building. Obviously, the office building has to spend more money for its energy demand by using solar PV instead of the current supply source. The higher portion of energy supplied by solar PV over total energy demand, the more negative net present value is accounted.

α	NPV (million VND)	USD equivalent (USD)	Solar PV(kW)
1	-256	-12,190	7
2	-512	-24,381	14
3	-768	-36,571	21
4	-1024	-48,762	28
5	-1244	-59,238	34
6	-1500	-71,429	41
7	-1756	-83,619	48
8	-2012	-95,809	55
9	-2268	-108,000	61
10	-2111	-100524	68

Table 4.1. Net present value and renewable energy options (Office building)



(a) Office building

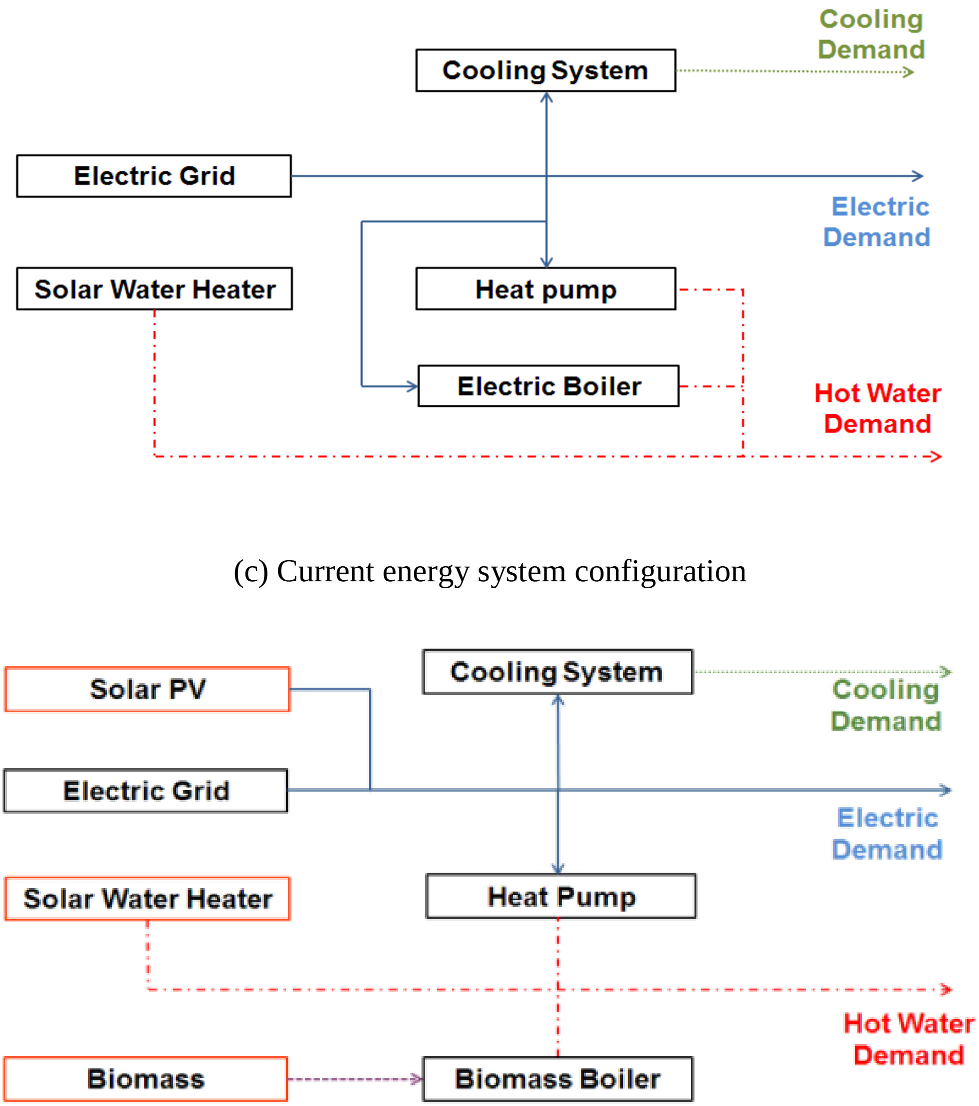


(b) Hotel

Figure 4.2. Net present value variation under different energy supply configurations

4.2. Integration of renewable energy into a hotel

Technically, the hotel demands both heat and electricity, it is possible to integrate not only Solar PV for electricity but also solar water heater and biomass boiler for heat. The area available for the installation of Solar PV and Solar water heater is 1000m2. The integration scheme of renewable solutions into the hotel is shown in Figure 4.3. Currently, the cooling demand and electric demand are supplied by electric grid, while the heat demand for water heating is supplied by both electric grid and solar water heater. The current percentage of renewable energy supply is 0.8%. Compare to the current system, the new energy supply system with renewable solution integrated is added with solar PV for electricity, biomass boiler and more solar water heater for heat.



(c) Current energy system configuration

(d) New energy system configuration

Figure 4.3. Current and new energy supply configuration (Hotel)

The analysis result of economic feasibility of integration of renewable energy into the hotel is shown in Table 4.2. According to that, for $\boldsymbol{\alpha} < \mathbf{6}\%$, the net present value increases linearly to the amount of renewable production put into the energy system (Figure 4.2b). Up to $\boldsymbol{\alpha} = \mathbf{6}\%$, the renewable energy options are only solar water heater and biomass boiler. The low cost of these two sources causes a saving of energy cost for the hot water demand, resulting in positive net present value (Table 3.3). For $\boldsymbol{\alpha} > \mathbf{6}$%, the net present value drops dramatically due to higher unit cost of solar photovoltaic, compared to current electricity tariff (Figure 3.7). The portion of heat demand for water heating acquires for 6% of total energy demand. That is the reason solar PV is added to fulfill the requirement of renewable energy percentage (Figure 4.4). Due to the area limit 1000m^2, the maximum portion of renewable energy production can be integrated into this hotel is 7.9%, at which the net present value goes near 0. Hence, it is economically feasible for the hotel to integrate renewable energy up to $\boldsymbol{\alpha} = \mathbf{7.9}$%. Anyway, to maximize the benefit, the hotel should integrate $\boldsymbol{\alpha} =$6%, where the capacity of biomass boiler is 55kW and the panel are of solar water heater system is 1000m^2. The energy demand and renewable energy supply patterns for $\boldsymbol{\alpha} = \mathbf{6}$% are shown in Figure 4.5, indicating that water heater and biomass boiler supply 100% of the hot water demand of the hotel.

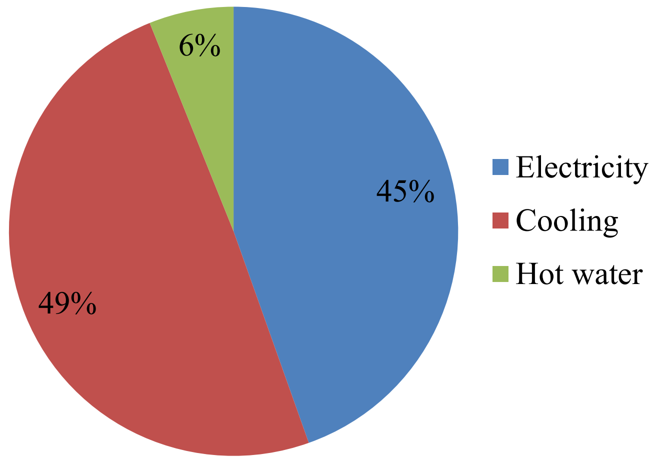


Figure 4.4. Energy demand distribution

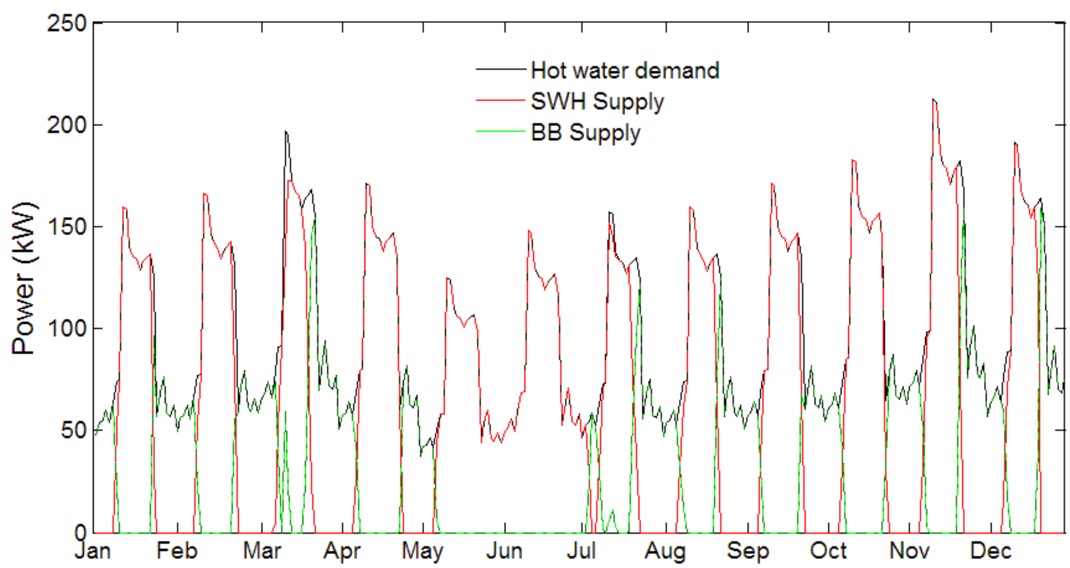


Figure 4.5. Hot water demand and supply patterns of the hotel for $\alpha = 6\%$.

α	NPV (million VND)	USD equivalent (USD)	Renewable integration		
			SolarPV (kW)	SWH (m^2)	BB (kW)
7.9	12	571	125	0	177
7.6	82	3,905	106	152	150
7	2,469	117,571	64	487	145
6	4,917	234,143	0	1000	55
5	4,083	194,428	0	941	0
4	3,178	151,333	0	751	0
3	2,245	106,905	0	564	0
2	1,335	63,571	0	376	0
1	41	1,952	0	188	0
0.8	0	0	0	152	0

Table 4.2. Net present value and renewable energy options (Hotel)

4.3. Energy policy suggestion

Because the negative net present value for both the hotel and the office building type are caused by the high cost of solar PV only, it is reasonable to suggest a subsidy policy to reduce unit cost of electricity supplied by solar PV.

According to Oh et al.[15], the unit cost of electricity by integration of solar PV is calculated as follow:

$$C_{Solar\ PV} = \frac{C_{product} - C_{replacement}}{E_{product}} \tag{1}$$

In which, $C_{product}$ is the annual cost to operate the solar PV system

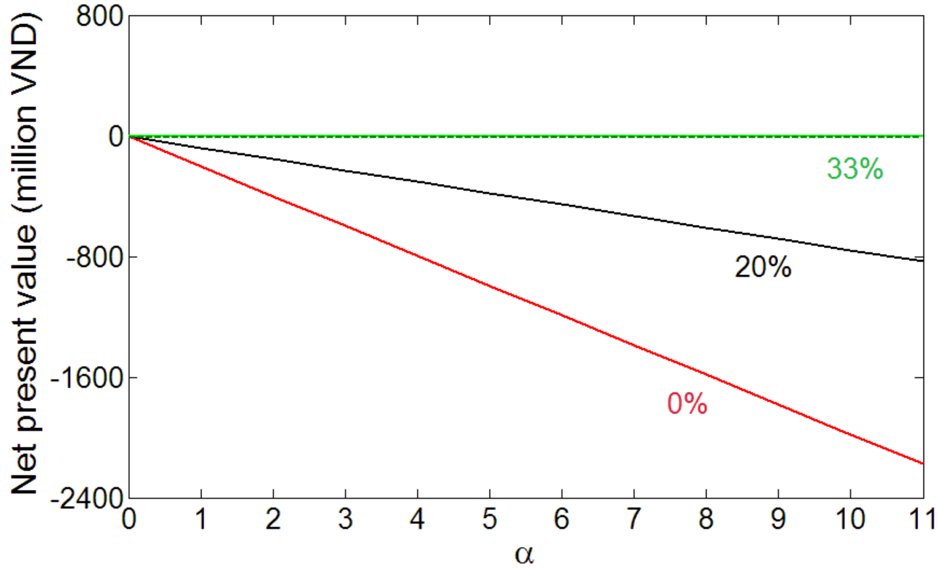
$$C_{product} = (1 + \emptyset)C_i \times CRF \tag{2}$$

And $C_{replacement}$ is the cost of the annual electricity produced by solar PV system, or $E_{product}$, which can be replaced by the current energy supply configuration.

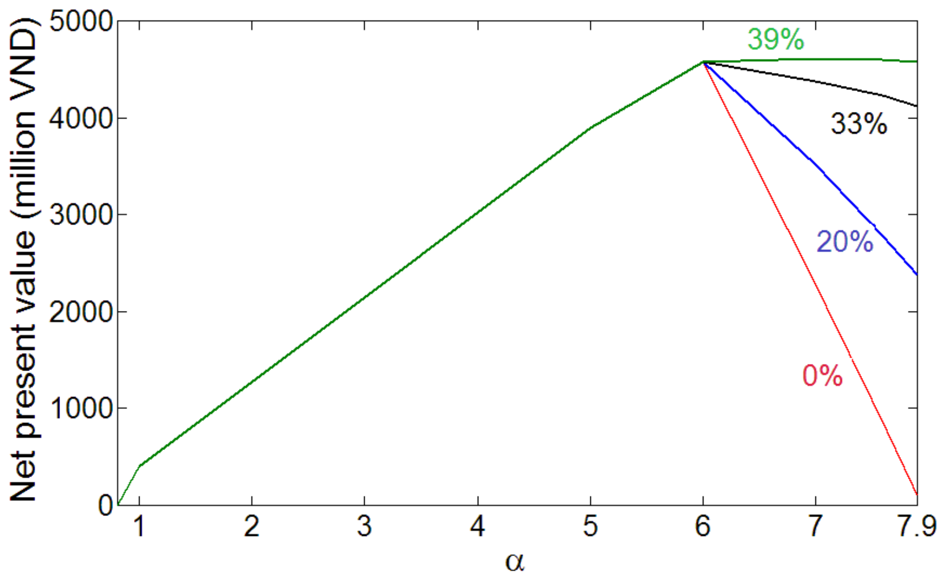
From equation (1) and (2), obviously, the unit cost of electricity by Solar PV can be reduced if there is a subsidy plan applied directly to reduce the initial cost C_i.

Figure 4.6 describes the variation of the net present value, or the economic feasibility, of the integration of renewable energy solutions into the two buildings, under different subsidy plans. As seen in Figure 4.6a., net present value of the integration for the office building is positive with a subsidy plan reducing at least 33% current initial cost of Solar PV systems. While a higher subsidy, which is 39%, would ensure the hotel to integrate more renewable energy percentage and still maximize the benefit it gets at $\alpha = 6\%$. (Figure 4.6b)

Since the subsidy is applied on the Solar PV only, it is helpful not only for the office building in this investigation but also for other buildings which demand only electricity to integrate solar PV.



(a) Office building



(b) Hotel

Figure 4.6. Net present value variation under different subsidies

Chapter 5. Conclusions

In this study, a quantitative approach was used to investigate the economic feasibility of integration of renewable energy solutions into an office building and a hotel in the south of Vietnam. Furthermore, the energy demand patterns of the two buildings were investigated. The energy demand of the hotel comprises of electricity, heat and cooling energy while the office building demands only electricity.

Net present value analysis showed that it is not economically feasible for the office building to use renewable energy under current cost of equipment. While for the hotel, it is possible to integrate renewable energy solutions for heat and electricity demand up to 7.9% without economic loss. Moreover, the hotel can maximize its benefit by supply all the heat demand (6% of total energy demand) by solar water heater and biomass boiler.

Finally, a subsidy policy was suggested to encourage public buildings in Vietnam to use more renewable energy. A plan supporting at least 33% initial cost of solar PV would make it economically feasible for the office building and other buildings which demand only electricity to integrate solar PV while a subsidy plan supporting that cost by 39% would encourage the hotel to integrate more solar PV.

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- Tuan An Group. (www.tuanan.com)
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Appendix

i. Estimation of energy demand of the office building

a. Assumptions

- The daily demand pattern of everyday in each month is the same.
- Because electricity for cooling is proportional to the difference between outdoor temperature and cooling destination temperature, the typical demand pattern for each month is estimated by outdoor temperature data.
- Office hours: 8 a.m. – 5 p.m.
- The demand out of office hours is taken to be equal to that in July.
- Year-round temperature data is provided by the Ministry of Construction, 2009[4].

b. Estimation of electric demand for air cooling.

$$E_j^i = E_j^{Jul} \times \frac{Outdoor\ temperature_j^i - 25}{Outdoor\ temperature_j^{Jul} - 25}$$

- E: Electricity demand for air cooling
- Cooling destination temperature: 25°C
- i: month index; i = Jan, Feb, … Nov, Dec.
- j: hour index; j =8,9,…,17. (Office hours)

ii. Estimation of energy demand of the hotel

a. Assumptions

- The daily demand pattern of everyday in each month is the same.
- The total electric demand is proportional to monthly electricity consumption.
- The cooling energy demand and water heating energy demand are proportional to the monthly occupancy rate.

b. Estimation of year-round electric demand

$$E_j^i = E_j^{Nov} \times \frac{Eletricity\ consumption^i}{Eletricity\ consumption^{Nov}}$$

- E_j^i: Total electric demand at j^{th} hour, i^{th}month
- i: month index; i = Jan, Feb, … Nov, Dec.
- j: hour index; j =0,1,…,22,23.

c. Estimation of year-round cooling demand

$$C_j^i = {E_C}_j^{Nov} \times COP_{Cooling} \times \frac{Occupancy\ rate^i}{Occupancy\ rate^{Nov}}$$

- C_j^i: Cooling energy demand at j^{th}hour, i^{th}month
- ${E_C}_j^i$: Electricity demand for air cooling system at j^{th} hour, i^{th}month
- $COP_{Cooling}$: Coefficient of Performance of Air Cooling system

d. Estimation of year-round hot water demand

$$Q_j^i = Q_j^{Nov} \times \frac{Occupancy\ rate^i}{Occupancy\ rate^{Nov}}$$

$$Q_j^{Nov} = \left({E_q}_j^{Nov} - \frac{Q_{HP}}{COP_{HP}}\right) \times \text{EBC} + {Q_{SWH}}_j^{Nov}$$

- $_j^i$: Heat energy demand at j^{th}hour, i^{th}month
- $E_{q_j}^{Nov}$: Electricity demand for water heating system at j^{th}hour, i^{th}month
- $_{HP}$: Heat generated by the heat pump at full load
- COP_{HP}: Coefficient of Performance of the Heat pump
- EBC: Total electric boiler capacity
- $_{SWH}{}_j^{Nov}$: Heat energy supply by solar water heater at j^{th}hour, November.

초 록

베트남은 재생 가능 에너지 잠재력이 큰 국가로 보이지만 이런 에너지원의 개발이 아직까지 제한되어있다. 재생 가능 에너지원의 개발이 제한되어있는 이유는 원가고 문제와 효과적인 촉진정책들이 빈약한 것이다. 이런 연구에서는 연구자가 두가지 에너지원인 태양 에너지와 바이오매스 에너지(biomass)에 관심을 두고 공공 건물을 위한 재생 가능 에너지 사용의 경제성 타당성을 평가할 것이다. Oh et al 이 발전시킨 효과적 방법은 베트남, 호지민시에서 호텔과 오피스텔 빌딩에 에너지를 제공하기위한 재생 가능 에너지 관리법과 해결법을 분석하는데에 사용된 것이다. 다시 말하자면 두 건물을 위한 재생 가능 에너지를 사용하기 위해 경제성 타당성이 분석된 것이다. 분석 결과를 바탕으로 연구자가 이 두 건물의 재생 가능 에너지를 사용하도록 권장하기위해 보조금 정책을 제시할 것이다.

주요어: 태양열 온수기, 태양 광 발전, 바이오매스, 에너지 수요 패턴, 에너지 정책, 순 현재 가치

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