Murdoch UNIVERSITY

RENEWABLE ENERGY TECHNOLOGY IN BUDDHIST MONASTERIES

PEC624 Renewable Energy Dissertation
For the Master Degree of Science in Renewable Energy

By
PEETI NGAMPRAPASOM
Student ID No. 30849625
Email Address: peeting@hotmail.com

Supervisor: Dr TREVOR PRYOR
Academic Chair, Energy Studies

School of Engineering and Energy
Murdoch University
Western Australia
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Declaration of Authorship

I declare that this dissertation is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any university.

Signed:

(Mr. Peeti Ngamprapasom)

Date: …16/7/2010….

“Science Without Religion is Lame,

Religion Without Science is Blind”.

Albert Einstein

Abstract

The importance of renewable energy technologies has become increasingly evident in the public mind in recent times. This has arisen during instances of energy shortage and oil price shocks, coupled with emerging concerns as a result of climate change effects. The attraction of renewable, natural energy sources such as wind, solar, hydro, geo-thermal and biomass, compared to the detrimental environmental impact of existing resources is obvious. The promise of renewable energy technology has provided hope to society's need for sustainable energy, as well as the survival of human kind in the future.

However, in the transition from fossil-fuel based technologies to renewable energy technologies, obstacles to change arise from the incumbency of vested interests. Thus, there is a pressing need to demonstrate to the public that renewable energy resources are practicable. Buddhist monasteries can be instrumental in this task. In countries, such as, Thailand, Myanmar, and Sri Lanka, monasteries play a social role as public centres for their communities. Not only do they deliver Dharma from the Lord Buddha, but they also model and teach their adherents how to conduct their lives in harmony with nature and the environment.

In this paper, two aspects of energy have been discussed in relation to their application to Buddhist monasteries, including the importance of energy efficiency and the significance of renewable technology. The Bodhiyana Buddhist monastery in Serpentine, was used as a site for a case study to examine both issues. The case study contains energy audits and renewable energy resource assessments which play a vital role in each of the issues. Subsequently, the paper explores the 'Noble Eightfold Path' of Buddhist doctrine by demonstrating the bridge to renewable energy technology. The terms 'Right Livelihood' and 'Appropriate Technology' are used in relationship between these two elements.

Acknowledgements

This dissertation of PEC624 Renewable Energy Dissertation is for the Master Degree of Science in Renewable Energy. My problem when started doing this unit was that I did not have my special interest into any specific kind of renewable energy technology, therefore on the project selection process I found myself depressed because I really did not know what I should do. This could happen to any student who had not had the issue in which one wanted to pursue. However, when time ran out, I picked up the project at the Bodhiyana Buddhist monastery to be my dissertation. I realized that this could unlikely be interesting for a majority of reviewers but it could be challenging in the way that as a renewable energy student, I should make use of anything in a facet of renewable energy.

This dissertation could not be completed without supports and encouragements from these following people and bodies. First of all, I would like to thank all lecturers and staffs at the Energy Studies Program, Murdoch University. This includes ones who involve in the existence of the Master Degree of Science in Renewable Energy for their impressive works in initiating, designing and operating the course. This dissertation can be considered as my attempt to mix up all pieces of knowledge from almost all of units I have learnt from this course in two valuable years. My special thankfulness also goes to my supervisor, Dr Trevor Pryor for his dedication and guidance throughout not only for my dissertation but also for my study since my first day in the university.

About the Bodhiyana Buddhist Monastery in Serpentine, WA, first of all I would like to mention my friend, Andrew Pascale who got me involved in the harnessing wind energy project for the Monastery, and also Dr Jonathan Whale who gave me informative advice when dealing with a wind turbine. My respectful gratitude to His Holiness Ajahn Brammavankso, the abbot of the Bodhiyana Buddhist Monastery in Serpentine, for his Metta (a Buddhist term for ‘compassion’) and his approval to use his property to be my case study. With all my respect and special thanks are given to Ajahn Brahmali for his tireless efforts to help providing all the monastery information and to walk me through all buildings in the monastery.

My gratitude must go to the Oil Refinery Contract Contribution Fund for its financial support, likewise, to the Department of Alternative Energy Development and Efficiency, the Ministry of Energy and the Royal Thai Government, for the approval of my trip to pursue my study.

As a Buddhist, with the holy force of my great merit-made doings, I would like to wish and bless all people mentioned above to be joyful, healthy and wealthy, to see clearer views in all perspectives, and to be able to determinedly and consciously handle all obstacles which might have come across. These blessings are also being sent to those renewable energy guys not only ones who devote themselves in renewable energy industry and academic institutions but also ones out there who have been installing the systems in very remote areas and/or poverty regions to help bring qualities of life for others.

Acronyms, Glossary and Terms

BOM	Bureau of Meteorology
BSWA	Buddhist Society of Western Australia
CFL	Compact Fluorescent Lamp
NASA	National Aeronautics and Space Administration
PV	Photovoltaic
REB	Renewable Energy Buyback
REC	Renewable Energy Certificate
RET(s)	Renewable Energy Technology (s)

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

The importance of renewable energy technologies has become increasingly evident in the public mind in recent times. This has arisen during instances of energy shortage and oil price shocks, coupled with emerging concerns as a result of climate change and the effects of global warming. The attraction of renewable, natural energy sources such as wind, solar, hydro, geo-thermal and biomass, compared to the detrimental environmental impact of existing resources is obvious. The promise of renewable energy technology has provided hope to society's need for sustainable energy, as well as the survival of human kind in the future.

However, in the transition from fossil-fuel based technologies to renewable technologies, obstacles to change arise from the incumbency of vested interests. Thus, there is a pressing need to demonstrate to the public that renewable energy resources are practicable. Buddhist monasteries can be instrumental in this task. In countries, such as, Thailand, Myanmar, and Sri Lanka, monasteries play a social role as public centres for their communities. Not only do they deliver Dharma from the Lord Buddha, but they also model and teach their adherents how to conduct their lives in harmony with nature and the environment.

In this first chapter brings you to find the principles and reasons of the initiation of this paper. The research motivation, the research question, the objectives and potential contributions and the difficulties behind the paper's writing up process are mentioned. Finally, this chapter ends with the structure of this dissertation in order to briefly explain the composition of it.

1.1 Research Motivation

Research motivation of this dissertation is composed of three paradigms:

- Buddhist Economic in response to a possibility of failure in the energy technology market
- Renewable Energy Technology (RET) is essential for sustainable development in response to climate change
- A Buddhist response to the climate emergency

Buddhist Economic in response to a possibility of failure in the energy technology market

Approaching how to sustain energy consumption by considering as the product of five terms in which it originates the total societal cost of providing energy services: (Lovins 1990)

- Population
- Stock of material artifacts' per capita
- Resource throughput to maintain each unit of stock (resource-efficiency)
- Energy consumption per unit of resource throughput (energy-efficiency)
- Cost and impact per unit of energy consumption (clean energy technology)

The only way to sustain energy consumption is to compensate for growth in the first two terms using the three latter terms. These three terms are related to modern improvements in technology with all means that technology can maximize the benefit of energy resource. However, can this trend be forever if we continue to develop our society without careful precaution? With economic perspective, knowing that energy price is increasing due to its scarcity leaves us a hard position to deal with the future energy costs.

The following discussion brings on the classical economic approach - The Club of Rome's book 'the Limits to growth' (Meadows et al. 1972) to explain the physical limit of earth that despite being promoted as a sustainable energy, the utilization of renewable energy resources will not be able to deal with careless development growth, the sustainable development cannot be achieved unless the energy demand is carefully addressed.

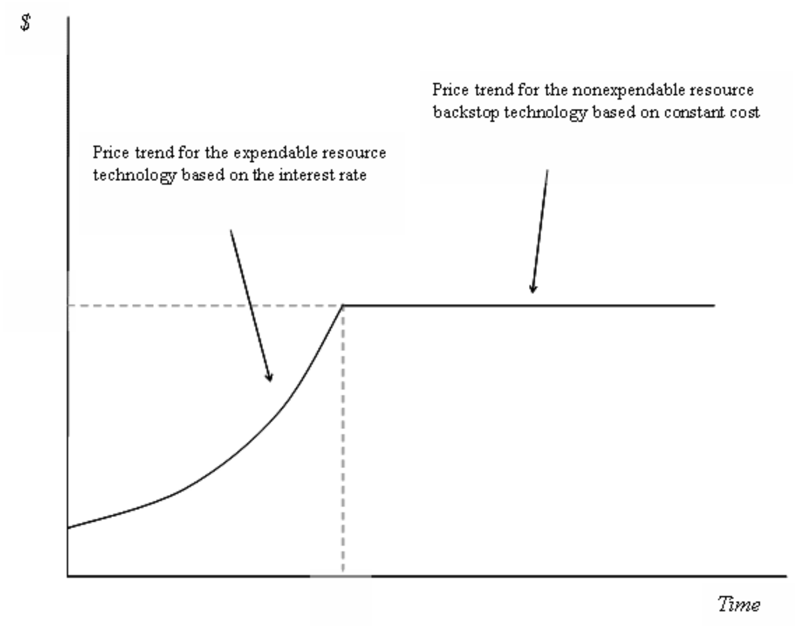


Figure 1.1 : Price to time trend of a backstop technology (Field 2001)

The hypothesis 'the Limits to growth' basically outlooks the world natural resources in which it will be running out in a coming year. In terms of energy supply, with the exponential growth in the economy which uses up the fixed stock of energy resource including fossil-fuel based and non fossil-fuel based technologies, makes the energy demand growth far more concerning than we might have thought. However, Dormbursh (2006) argues that in economics this will not happen because of two factors. First, technical change alters us the way to produce more but using fewer resources. And second, as a result of demand-supply characteristic, if resources run out, their prices rise, then producers will shift to other substitutes (Dornbusch 2006). In response to the first factor, Dennis Meadows, one of the author of the 1972's book responds to this argument saying that he understands the technical change could influence the outlook of 'limits to growth' but he insists that we cannot avoid the growth limit, in fact we can only delay it because we are actually facing the physical growth of raw material and natural energy resources which flows in the limit of a finite planet (Meadows 2009). The second factor accommodates the existence of renewable energy technology.

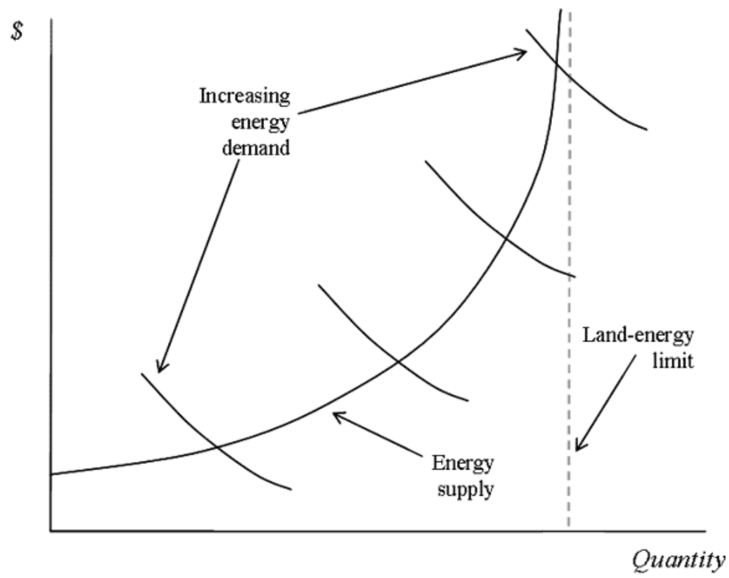


Figure 1.2 : A limit to economic matter-energy throughput using Ricardian Land and Solar Energy as a backstop technology candidate (McHugh 2006)

In the consideration of renewable energy to the Limits to growth concept, theoretically, only a non-exhaustible energy resource may give us a room to adapt to. This concept introduces the term 'backstop technology' (Nordhaus 1973). Basically, a backstop technology potentially represents an economic viable cost of technology at a constant price as the cost trend can be seen in Figure 1.1, McHugh (2006) concludes about this hypothesis that a backstop technology can be approached in two ways: the technical knowledge that has already existed somewhere in the economic background but it just awaits viability, and the technology as a result of induced technology change. He (2006) then provides the consideration of solar energy as a leading backstop technology candidate (another potential candidate is fusion reaction) within a fact that only solar energy has no constraint in dealing with the finiteness of materials within the global system implying that if energy demand continues increasing, sustainable energy is impossible (See Fig. 1.2).

Given the preceding discussion, a backstop technology will not be a solution for energy scarcity due to a limit of energy production on supply-side. On demand-side, therefore, regarding sustainability, energy consumption must be taken into account seriously by considering two main keys to a solution of energy demand which are: world population and energy consumption per capita because essentially the amount of energy used in the world is equivalent to a result of the global population multiplied by the energy consumption per capita.

Renewable Energy Technology (RET) is essential for sustainable development in response to climate change

Figure 1.3 illustrates the humanity's ecological footprint has overtaken its ecological footprint since the mid-1980s with its trajectory to 1.5 earths by the year 2010. The ecological footprint is equivalent to the amount of land and water needed to sustain life and absorb wastes, whereas the figure of 1.5 earths elaborates on the conclusion that we consume more resources and produce more wastes than the earth can produce or absorb respectively (Maczulak 2010). This takes both two factors: world population and effects to ecological footprint.

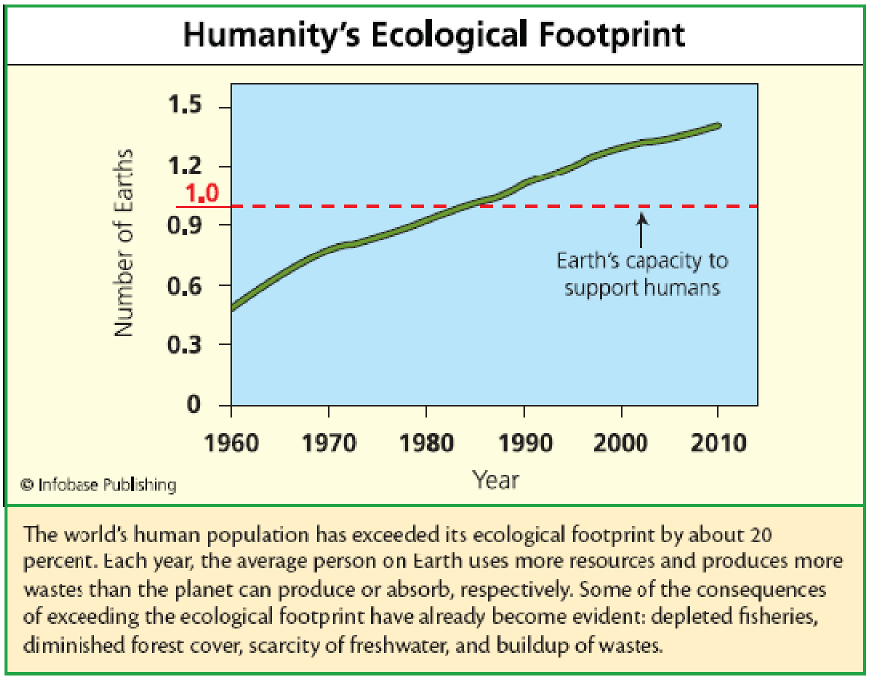


Figure 1.3 : Humanity's Ecological Footprint (Maczulak 2010)

To the extent of world population, it is believed that world population will be stabilized by about 2080, as we see the continuation of the declining rates of population increase nowadays. But before that time, the world needs to accommodate another three billion of population, then after 2080, the global human population will gradually decline (Garnaut 2008). However, the expansion of production will be increased far more than the population per se due to the rising output of production per capita. This inextricably links to the energy generation because all products need energy to energize the production lines leading to ecological footprint, for example, energy produced using coal mine needs land to extract coal underneath, then coal burning emits CO_2 that cause global warming. This example allows RETs to replace the use of coal that damage and pollute the environment which reduces ecological footprints (Maczulak 2010).

A Buddhist response to the climate emergency

Buddhism has been used to explain a consequence of what we have done as defined by 'karma'. It is also believed that all elements in nature accommodate sentient beings. This characteristic of Buddhism implies the answer of why Buddhists respect nature. Having said that we are not to exclude the fact that humankind must survive and create civilization and that we have to invade nature to sustain our lives, but the most important aspect we must take into account is how much we need to do it. In recent years, we are facing a well-known 'Climate Change' effects. It has become firmly evident that all environment damages regarding climate change are caused by human. Inevitably, we need to change our behaviors to change our consequences. Buddhism believes that the only way to change our existing environment is to change our inner mind (Jade Buddha Temple 2009). Buddha teachings - 'the middle way" should then be stressed to find ourselves back when we are lost in a pursuit of high-consumption lifestyles. This is a shared responsibility of not only for Buddhists but all of the world's religions to enhance a sense of social responsibility of all members in society.

1.2 Research question

Within research motivation stated above, inarguably the content of the dissertation could end up too broad. Accordingly, the research question has been created to focus on a synergy of renewable energy technology and Buddhism. This dissertation poses the following research question:

Main Research Question: "How can Buddhist monasteries best use renewable energy to minimize their consumption of conventional energy?"

Furthermore, another challenge implicit in this question is to find a relationship and contribution they both can interact to each other. A relationship between renewable energy technology and Buddhism is assessed under these following three areas which are:

1. Renewable energy technology in Buddhist monasteries throughout the world
2. Implications for renewable energy system design for Buddhist monastery
3. A role of Buddhism in promoting renewable energy technology

1.3 Objectives and Potential Contribution

This research has set up objectives including:

1. to identify the motivation of renewable energy technology deployed in Buddhist monasteries throughout the world
2. to use the Bodhinyana Buddhist Monastery in Western Australia as a case study and an example for other monasteries in regard to energy efficiency and renewable energy technology
3. to use faith and belief towards the religion to promote RETs

Among a world population of 6.8 billion (U.S. Census Bureau 2010), Buddhism is a religion to about 300 millions around the globe. Buddhism plays an important part in some countries especially in Asia. A Buddhist life style can be thought of as a simple life, trying to consume as less as possible. However, in reality nowadays, there are needs of electrification to proceed some actions, particularly in a night time when lighting is in need. Furthermore, some of Buddhist monasteries are situated within a modern society which is almost impossible to get away from the need of electricity, although not for the Buddhist monks themselves, but there is still a need for visitors or Buddhist adherents who come to practice the Buddha teachings. The potential contribution of this research then aims at being a guideline for the Buddhist monastery to assess the natural resource in order to make use of RETs. At the same time, the monastery should be able to help in promoting RETs by taking a chance to show and teach the followers to emphasize the importance of nature.

1.4 Difficulty

In writing up this dissertation, only the installation of RE systems at monasteries can be explained using a technical approach while other aspects are hypotheseses as a generic character of religious issue meaning that they could not be proved in a laboratory or a field within a limited timeframe. Another thing should be mentioned regarding RETs in Buddhist monasteries is the reviews of the documents, articles, news, etc. have mainly been extracted from internet resources. The author has realized the limitation of the information due to the fact that the topic is likely interesting for only a minority of reviewers. Nonetheless, there are some interesting issues useful and worth understanding.

Like other religions, Buddhism aims at raising goodness in people’s mind. Likewise, every religion anticipates good actions, good talks and good thoughts from all members. One way of examining and sharpening people’s mind, meditation has been mentioned for many years. Not surprisingly, there has been an attempt to mix up between the advance technology and Buddhism, specifically in neuroscience. This is because it is believed that a meditation is a practice that can change neurological system (Begley 2007). His holiness Dalai Lama is the one who has dominated and involved in this field of science for quite a while. His intention has become evident since he sent his Buddhist monks to have further study in neuroscience. That shows the relationship between Buddhism and neuroscience. Nevertheless, in a field of renewable energy technology there has been no dissertation that studies about RETs using Buddhist properties. Fortunately, there are some articles found in internet explain about the installation of Solar PV in some monasteries in Nepal and Tibet. Others use Buddhism to link with environmental protection movements using law of karma doctrine to explain consequences of what we have done which emerges the Climate Change effects as a result.

About the assessment of renewable energy resource for the Bodhiyana Buddhist Monastery in Chapter 3, wind data from the bureau of meteorology at three hrs interval were provided. This could only be used to find the average wind speed instead of a better site evaluation if more detail of data were available. Therefore, a guideline will be found in the chapter is only a basic guideline provided for other monasteries as if ones would like to implement the renewable energy development in their territories. Also, it is worth noting that gas consumption in the Monastery in Chapter 3 is contributed to heating systems. The gas heating systems are installed in the sanctuary and eight huts and for cooking in the kitchen. However, there is no gas pipeline from the utilities available to the monastery because of its remote area, then the monastery has gas retailers delivered them gas tanks (in sizes 45 kg and 9 kg) subject to their orders. Therefore, it is difficult to identify the reasonable quantity of gas consumption since they order gas tanks when they want, not when they need. With this ambiguous information only the estimated average gas consumption of 1.5

to 2 kilogram per day is considered if biogas is conducted in the monastery. However, at this stage, only electricity is focused.

1.5 Structure of Dissertation

As discussed in the introductory section of this chapter – this chapter provides some ideas of why this dissertation has been written. In Chapter 2, it reviews RETs in Buddhist monasteries throughout the world. Simultaneously, it provides a brief description of Buddhism and gives the motivations of why RETs installed in Buddhist monasteries. Chapter 3 describes RETs in a real situation by using the Bodhiyana Monastery in Western Australia as a case study. This conducts energy audits at the beginning and ends with the process of harnessing renewable energy resources. As a consequence of the installation of solar PV at the monastery a comparison of before and after the installation has also been studied. Chapter 4 provides a thought towards Buddhism in regard to RETs. Some of Buddha teachings have been used to meet the solution of energy and environmental crisis. Chapter 5 concludes main ideas mentioned in this dissertation.

Chapter 2: Renewable Energy Technology in Buddhist Monasteries

This chapter introduces that Renewable Energy Technology is not new for Buddhist monastery. Literature reviews show that there are RETs installed in monasteries in some countries throughout the world, especially in Asian countries like Nepal, Singapore and China where Buddhism has been flourishing. This chapter will find out the motivation in those installations and will lend itself as a guideline for small-scale approach to the installation of renewable energy applications which could be benefits for Buddhist monasteries or other residential sector members.

2.1 Scope of Buddhist Monasteries

Buddhism has been in the globe for more than 2,500 years ago. It was the Lord Buddha, Siddhartha Gautama, who was born in (the present-day) Nepal in the year 563 BC (Dhammika 2005), found out the truth of nature: suffering, liberation, emptiness and interdependence. As time passes by, Buddhist history diversifies its perception towards Buddha teachings into three primary “vehicles”. The Buddhist vehicles, in other words – tradition of thoughts and practices, are classified to: Theravada Buddhism, Mahayana Buddhism, and Tantric Buddhism. Even though adherents of all three vehicles can be found throughout the world but a majority of adherents in each one of the three primarily exists in the following areas in the world:

- Theravada Buddhism, mostly in Southeast Asia,
- Mahayana Buddhism, mostly in India, China, and parts of Southeast Asia,
- Tantric Buddhism, mostly in India, Tibet, Japan and in the West.

Note that it is common for the adherents of all three traditions to participate in other tradition's ritual and practice due to a great degree of similarity in principles and thoughts. Therefore, this paper considers all three traditions as one religion - Buddhism.

Figure 2.1 : Buddhist monks in Theravada Buddhism (www.angkor-wat-net.com 2010)

Figure 2.2 : Buddhist monks in Mahayana Buddhism (www.buddhanet.net 2010)

Figure 2.3 : Buddhist monks in a Tibetan Tantric order (BBC 2010)

2.2 Main characters of Buddhism

Buddhism comes from the word 'bodhi' meaning 'awakening'. It was the Buddha himself who awakened when he was 35 years old. What the Buddha found on the enlightening day were enormous but only a path to enlightenment that is the most important, therefore, the doctrine of Buddhism aims ultimately at providing a path to Nirvana (overcoming suffering, attaining true happiness and contentment). In doing so, one of his teachings: the Noble Eightfold Path (Dhammika 2005) is used in this paper which will be discussed later on. However, at this stage it is worth stating the outcome of practicing Buddhism the website 'Buddhanet' has guaranteed including:

> " *- to lead a moral life,*
> *- to be mindful and aware of thoughts and actions, and*
> *- to develop wisdom and understanding" (Buddhanet 2010).*

Another teaching the Buddha has taught about the interdependence co-arising, or in Buddhist term 'Prati-tya-samutpa-da' in which all lives in the world are cooperative and harmonious, only the interconnection of all lives that sustains all lives. This opens our mind to love and share with others. One of the Buddhist scripture - the Sutta-nipata, gives the Buddha's view more precisely as quoted:

> *"whatever living beings there be: feeble or strong, tall, stout or medium, short, small or large, without exception; seen or unseen, those dwelling far or near, those who are born or those who are to be born, may all beings be happy. Just as a mother would protect her only child at the risk of her own life, even so, let him cultivate a boundless heart towards all beings. Just as a mother would protect her only child at the risk of her own life, even so, let him cultivate a boundless heart towards all beings" (The Sutta-Nipata 1985).*

Given the above Buddha teaching provides a chance to environmental-friendly activities in response to climate change and the replacement of pollution emitters in fossil-fuel based technology with RETs.

2.3 Renewable Energy Technology in Buddhist Monasteries

2.3.1 Motivations to RETs in Buddhist Monasteries

The main motivations that drive the implementation towards RETs are:

- Electrification in rural area where grid connection are not available. Most cases in this category can be found in developing countries e.g. Nepal, Tibet, Thailand, Cambodia etc.
- Clean energy where grid connection is available. Mostly, clean energy campaign works well in developed countries as it favors the governmental incentives in implementing the clean energy project e.g. Australia, Singapore etc.

Figure 2.4 : Renewable energy applications in Poh Ern Shih Temple in Singapore (Tobias 2009)

2.3.2 Affordability

One thing that needs to be emphasized is the monasteries are non-profit organizations and living on the budget from donation. There are three types of donations that initiate the installation worldwide which are:

(Reviews of articles in relevant to these followings can be found in Appendix):

- The donation for monastery support themselves, these can be found in developed countries for example Australia, Singapore – these monasteries mostly are motivated to use RETs because of clean energy purpose, or want to reduce energy bills, or aware of uncertainty price in fossil-fuel based energy, and so on.

- The donation for monastery supports not only for themselves but for others as well, for example, Taiwan-based Buddhist Compassion Relief Tzu-Chi Foundation, where the monastery backed up the project in Afganistan (Brettman 2010)

Figure 2.5 : Solar PV in Bangladeshi Temple (Khursheed-Ul-Islam 2006)

- Donations to funding bodies established to help rural people, including Buddhist monasteries in rural areas. These groups of people can be found mostly on projects in Tibet and Nepal.

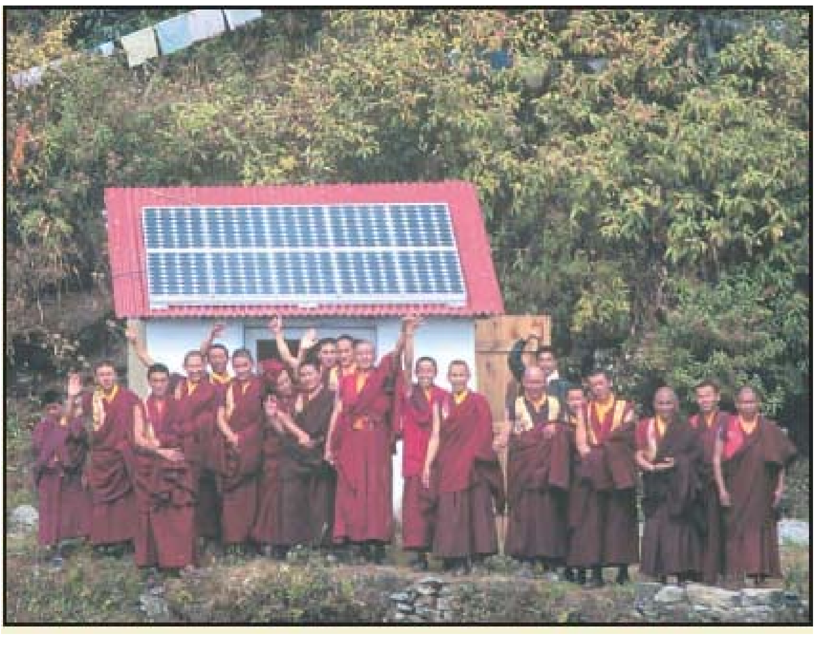


Figure 2.6 : Solar PV in Tibetan Monastery (Ramsey 2002)

Why donation?

Donation in Buddhist term is Dhana. Dhana in Buddhism is a way to practice yourself to be independence, to get yourself away from craving, desire, greed and finally away from sufferings as a destination of Buddhism. Buddhism sees these feelings as a threat to your success of practicing Buddha teachings. Dhana, also relates to Metta, Metta is a Buddhist term for Compassion. You would like to see others are happy, not yourself. This is a significance of Metta or Compassion.

Figure 2.7 : Buddhist monks are watching the wind turbine installation at Thai Forest Tradition Temple in Thailand (www.chivit-itsara.com 2009)

2.4 Benefits to Buddhist Monasteries

Apart from reducing the energy bills for the monasteries where power grid connection are available, benefits for the monasteries in rural areas are similar to rural people where kerosene lamps can be found everywhere with a little difference in detail including:

- reduce risks from lung cancer in inhaling smoke in the house everyday

- open an opportunity for residents (monks or young monks) to study Buddhist texts and to do other activities in night time
- help local people near the monastery coming to monastery to make use of the electricity (consider that monastery is a public center where local people are gathered to do activities not only for religion but also for their society
- slow down ruin of the murals and ancient texts from soot especially in Tibetan Monasteries
- likewise, in the place where fuel wood is used and deforestation is a major problem, RETs can be a substitute

Chapter 3: Bodhinyana Buddhist Monastery, Western Australia, Australia

In this chapter, the synergy of Buddhist monastery and renewable energy technology has been examined. A case study of a real situation using the Bodhiyana Buddhist Monastery in Jerrahdale, WA shows that RETs is practical. In order to identify load demand and understand the use of energy, an energy audit has been conducted. Energy efficiency provides opportunity for the monastery to reduce its energy bills. In the end of this chapter, a basic guideline of renewable energy development of wind and solar energy is provided.

Figure 3.1: A Buddhist Sanctuary in the Bodhiyana monastery

3.1 Bodhinyana Buddhist Monastery

Bodhinyana Buddhist Monastery is one of the important religious centers in Western Australia. It is located on top of the hill of Darling Ranges in Serpentine. The monastery lends itself as a meeting point for those Buddhists who faithfully come to the monastery to pay homage to the Buddha, to give foods and donations to monks and most importantly to learn and to question about Buddha's teachings from the monks. Bodhinyana monastery was established on 1 December 1983 and named after the great teacher Ajahn Chah – the Thai Buddhist Master. Bodhinyana implies the wisdom of enlightenment. It has anticipated that the monastery would provide an ideal environment for the monks who dedicate their lives to Buddha teachings. This is why the monk has built the monastery beneath the trees and within nature (www.bodhinyana.org.au 2010) This holy place is under supervision of Venerable Ajahn Brahmavanso Mahathera, also known as Ajahn Brahm, the Abbot of

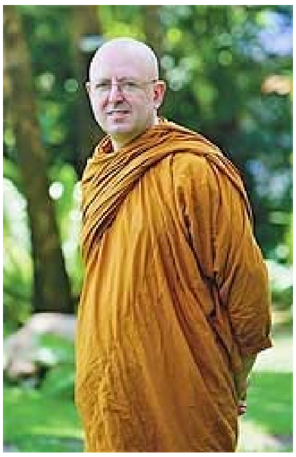


Figure 3.2: Venerable Ajahn Brahmavanso Mahathera (Buddhistchannel.tv 2010)

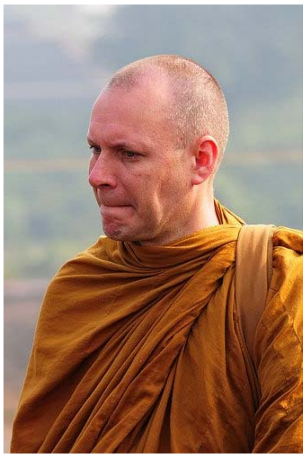


Figure 3.3 : Venerable Ajahn Brahmali

Bodhinyana Buddhist Monastery. Ajahn Brahm was born in England but inherited thoughts and philosophy from the Thai Forest Tradition in Thailand. He was awarded the John Curtin Medal in 2004 for his vision, leadership and service to the Australian community. He is now also appointed the Spiritual Director of Buddhist Society of Western Australia (BSWA), Spiritual Advisor to the Buddhist Society of Victoria, South Australia, and Spiritual Patron of The Buddhist Fellowship in Singapore (BSWA 2009).

According to Ajahn Brahmali – a senior monk who works as an assistant of the abbot, who has been assigned from Ajahn Brahm to harness renewable energy for the monastery, a number of Buddhists and visitors come in and out the monastery varies from 10 people per day minimum to 2,000 people per day maximum. The maximum number depends on the special Buddhist event for example 'Visakha Bucha day', the day of remembrance of the lord Buddha's birthday, his enlightenment day, and his death day in which can be considered a biggest event when most Buddhists want to participate in the ritual to remind the importance of the existence of the Buddhism. However, the average number of people per day can be roughly estimated to be around 20 people per day.

Regarding residents at the monastery, note that not only monks who live in the monastery, but also there are laypeople who want to be a monk, awaiting ordaining and acting like staffs at the monastery to clean up the monastery and to take care of the monks. These people are so-called 'Pa-Khao' meaning 'white robes' in Thai. Also there are two guest houses: one for male and one for female; these houses are for visitors who want to stay overnight at the monastery and for the 'angarikas' – ladies who practice Buddhism. A number of residents in the monastery can be categorized and put into a tabular form as shown in Table 3.1.

Table 3.1: A number of residents at the Bodhiyana Buddhist monastery

Personnel	Building Name	Total
A abbot of monastery	Ku-Ti-Chao-Ar-waad	1
Buddhist monks	Ku-Ti (a hut)	19
Pa Khao	Pa Khao	4
Guest	Guest House	
• Male		3
• Female (including Angarikas)		3
	Total	30

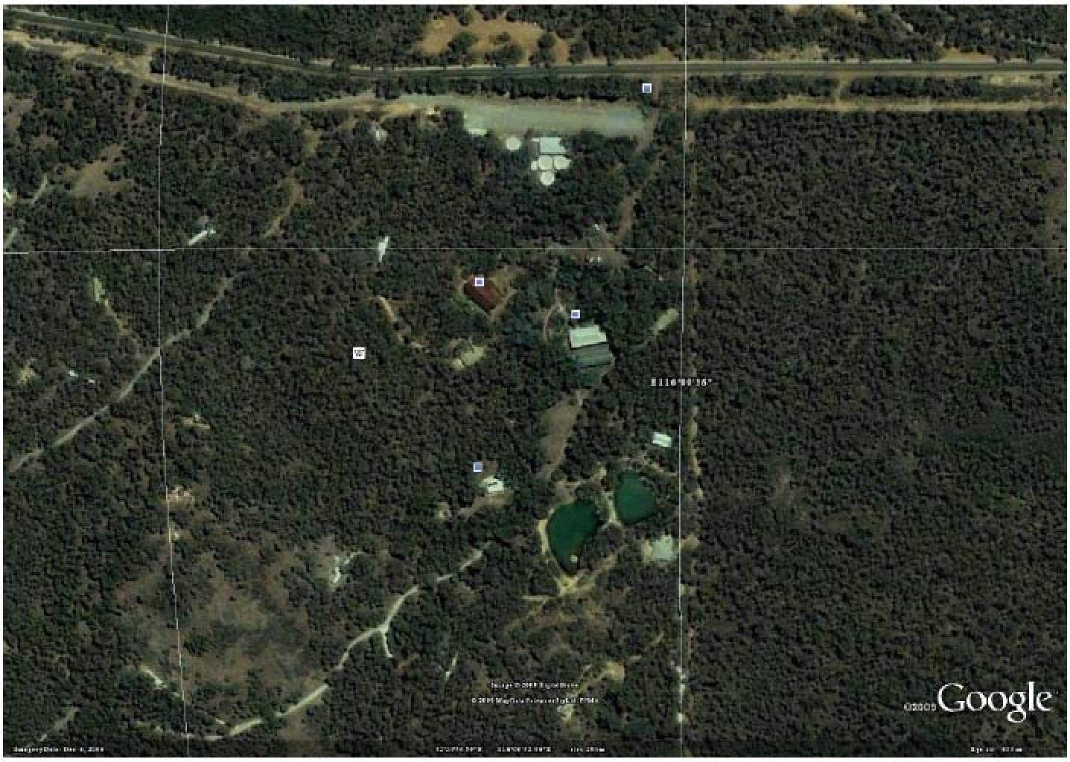


Figure 3.4 : Aerial photograph of the Bodhinyana Buddhist Monastery from Google Earth (32˚ 24’ 53.22’’ S, 116˚ 0’ 33.39’’ E) (Google 2010)

3.2 Energy Audits for the monastery

3.2.1 Purpose

This audit is to evaluate the manner of energy consumption within the Bodhinyana Monastery, Serpentine in order to assess how to reduce the current energy consumption.

3.2.2 Objectives of Audit

The objectives of this energy audit are:

1. to determine the amount of energy consumption at the monastery
2. to assess how energy is consumed
3. to recommend what should be done to reduce this energy consumption

3.2.3 Information Sources

This audit is compiled from:

1. Billing data
2. Site inspections
3. Use and occupancy information supplied by Ajahn Brahmali

3.2.4 Description of the monastery energy consumption

The Bodhinyana Buddhist Monastery is a forest tradition style Buddhist monastery. The establishment of the monastery has been expected to blend in a nature as a main theme of the monastery concept design. Having said that, most buildings which are huts for monks are scattered radiating out from the central area where the two floors meditation hall, the kitchen/dining hall sits on. Other buildings are a Buddhist sanctuary (locally called 'Ubosot' or 'Bot'), one 'Pa-Khao' house, two guest houses, a workshop and an ablution block. All these buildings are in use but how often and how much energy are used depends on an importance of each day of a year, i.e. it varies up to Buddhist events when a number of guests increases significantly.

3.2.5 Energy Use

Renewable energy technology is not new for the monastery since a water pumping system and electrification for monks' huts are provided by the solar photovoltaic technology. However, the main energy supply of monastery is from a grid connection network as the 33 kV transmission line passes through its properties along the Kingsbury Drive. Like other states where electricity providers and retailers are not the same company, while Western Power is the electricity provider, Synergy is an electricity retailer in this area. Several power metering options are available for Synergy's customers allowing decision to be made to maximize benefit from the consumptions (Synergy 2009); nonetheless, the monastery has chosen time-of-use based SM1 Smart Power Tariff to direct the cost of energy for it.

Conforming to AS/NZS 3598:2000 Energy Audits, at least two years consecutive energy billing history has been compiled. Not surprisingly, all bills have been put in folders and kept in a store room and never been comprehended. To gain maximum benefit from an energy audit, energy management program should be introduced. Based on the information obtained, Figure 3.5 depicts the graph showing average electricity consumption per day in each month. This shows more accurate view of energy consumption rather than consumption as shown in the bills.

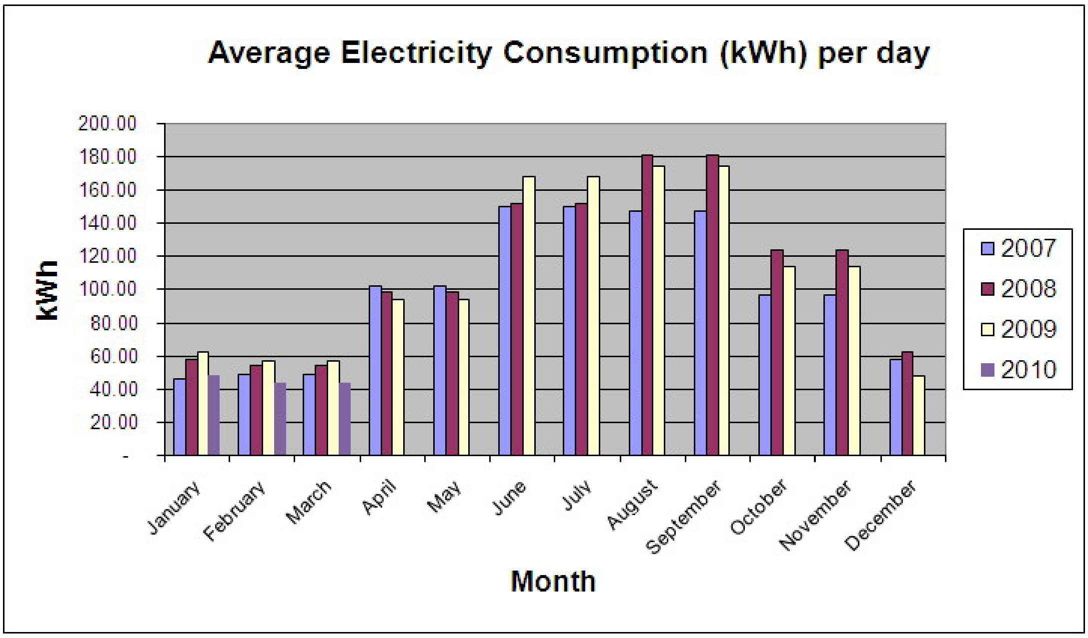


Figure 3.5: Average daily electricity consumption (kWh) per day throughout a year from 2007 to 2010

From the graph (Fig. 3.5), it can be concluded that seasonal effect has played a major role in energy consumption for the monastery. Due to its location on the hill, slightly lower temperatures than average temperatures in Perth throughout a year makes the place a bit cooler in winter and more comfortable in summer. This reason accommodates the fact that those heating space appliances have been used dramatically during winter. There is also a trend of incremental growth of energy need from 2007 to 2010. However, this trend has to be evaluated carefully since the number of residents has varied throughout a year.

3.2.6 Tariff Information

As mentioned earlier, several options of 'time of use' based energy management regime have been provided to Synergy's customers in the network, so-called SWIS (South West Interconnected System). The monastery has chosen SM1 Smart Power

Tariff for its electrification. Synergy SmartPower® is a residential product that allows you to take advantage of different electricity rates, depending on time of use. Electricity used in the cheaper time periods reduces electricity bill (Synergy 2009).

Extracting from energy bills charged on the monastery, this tariff is inclusive of supply and electricity charges as follows:

- Supply charge 25.1 cents per day
- Electricity charge
  - Off-peak 9.21 cents per unit (kWh)
  - Weekend shoulder 14.31 cents per unit (kWh)
  - Weekday shoulder 19.50 cents per unit (kWh)
  - Peak 31.97 cents per unit (kWh)

Note that these rates have been changed due to cost of electricity generation changed over time. Periods of time of use scheme are as follows:

- **Weekends all year round**
  - Off peak 9pm – 7 am
  - Weekend shoulder 7am – 9pm
- **Summer (October to March) Weekdays**
  - Weekday shoulder 7am – 11am, 5pm – 9pm
  - Peak 11am – 5pm
  - Off peak 9pm – 7am
- **Winter (April to September) Weekdays**
  - Peak 7am – 11am, 5pm – 9pm
  - Weekday shoulder 11am – 5pm
  - Off peak 9pm – 7am

It is worth noting that in order to assess energy consumption, hourly energy consumption should be recorded. Smart meter can serve the task in this regard. However, in WA, only approved energy smart meters can be installed for several reasons, subject to safety (National Solar Schools Program 2009). The main purpose is to identify energy use at different time-of-use during a day. Figure 3.6 extracts fractions of energy use at different time-of-use in each period throughout a year. The trend of energy use is relatively consistent.

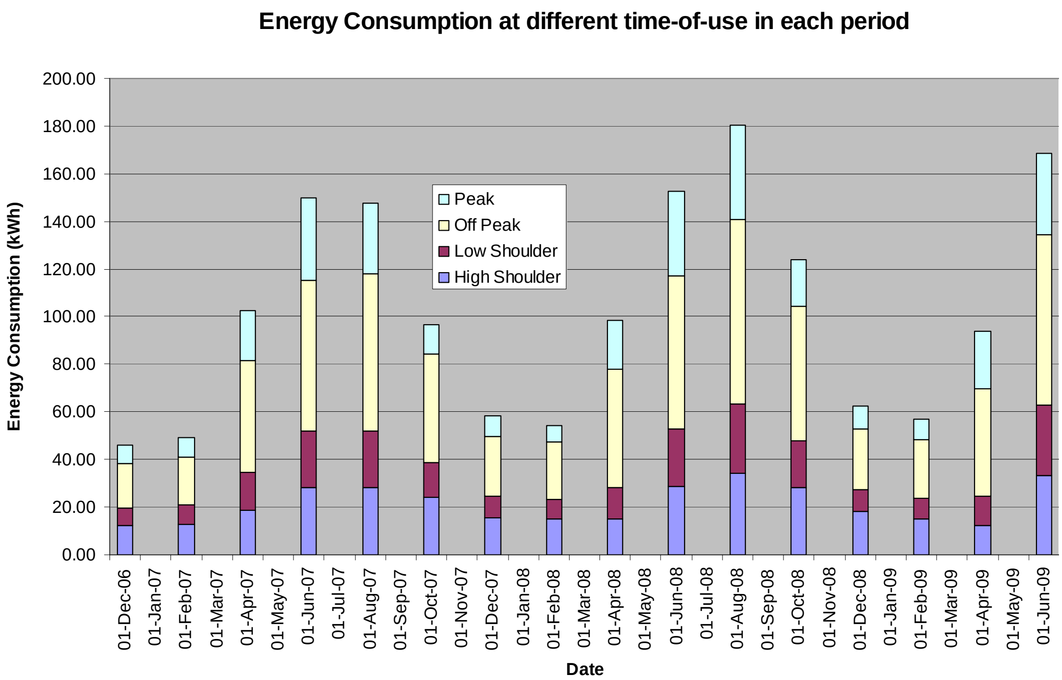


Figure 3.6: Fractions of energy use at different time-of-use in each period

Nonetheless, it is still worth considering energy consumption at peak and high shoulder periods as shown in Figure 3.6 in order to find the ways to minimize energy bills in a response to the fact that not all residents understand patterns of time-of-use energy management in their own property, therefore, it is a crucial task to the monastery to educate its residents.

3.2.7 Energy Saving Options

One thing which is worth remembering before the implementation of harnessing the renewable energy resource will be conducted, is to find the way to reduce the energy consumption or to maximize the use of the existing systems, as referred to energy efficiency. Some issues are considered to succeed the task for the monastery but not all of them can be used as stated below:

3.2.7.1 Lighting retro-fit options

From Table 3.2 shows lighting systems are everywhere but only a few options can be deployed. The obvious one is to change the incandescent globes to CFL. There are atleast two of 100 w incandescent globes in the female guesthouse needed to be replaced as soon as possible while other incandescent globes should be replaced respectively.

Figure 3.7: Incandescent Bulb (Mclaughlinquinn.com 2009)

Figure 3.8: Compact Fluorescent Lamp (CFL) (www.buildinggreentv.com 2007)

Replacing the old magnetic ballasts with electronic ballasts saves 2 watts the ballast power draw per fitting (www.alinehomecare.com 2010). Fittings can be changed from T8 size to T5 size, which corresponds to a drop in power consumption from 36 watts per tube to 28 watts per tube. Other options including the use of lighting sensors, occupancy sensors and dimming control are good options for reducing lighting costs in areas where the lights do not need to be on for significant periods of time (Galasiu et al. 2007). Daylight harvesting sensors utilized on the fittings also allows the power supply to the lamps to be turned down according to the amount of natural light that hits the sensors.

Table 3.2: List of electronic appliances used in the Bodhiyana monastery

No	Appliances	Amount	Power (W)
Meditation/Kitchen Hall			
Upper Floor			
-	Fan (Ceiling Type)	3	60
-	CFL	12	15
-	CFL (Corridor)	6	15
Lower Floor			
-	Incandescent (Dining Room)	6	60
-	CFL (Corridor)	3	15
Kitchen			
-	CFL	4	15
-	CFL	1	15
-	Microwave	1	1,400
-	Kettle	1	2,400
-	Refrigerator	2	600
Office			
-	Kettle	1	2,400
-	Fax machine	1	53
-	Heater	1	1,000

-	Printer	1	638
-	CFL	1	18

Buddhist Sanctuary

#	Outside			
	-	CFL (corridor)	6	15
	-	CFL (bell tower)	1	15
	-	Water Pump	1	1,600
#	Bedroom			
	-	Heater	1	1,000
	-	CFL	1	15
#	Library			
	-	CFL	2	15
	-	CFL	3	15
	-	CFL	1	15
	-	Laptop Computer	1	85
	-	CFL	2	15
	-	Ventilator	1	30
#	Inside			
	-	CFL	14	15
	-	Spot Light	3	250
	-	Fan (standing type)	1	75
	-	Ventilator	6	30
	-	CFL	2	15
	-	Stereo	1	240

Pa Khao House

-	CFL (Outside)		14	15
#	In 4 rooms			
	-	CFL	4	11
	-	Heater	4	1,000

	- Kettle	4	2,400
	- Halogen desklamp	4	50
Guest House - Male			
-	CFL (outside)	1	15
-	Vacuum machine	1	1,600
#	In 3 rooms		
	- CFL	3	18
	- Heater	3	1,000
	- Fan	3	70
Guest House - Female			
-	CFL (outside)	1	9
#	*Room 1*		
	- CFL	1	14
	- Heater	1	1,000
	- Incandescent	1	75
	- Kettle	1	2,400
#	*Room 2*		
	- Incandescent	1	100
	- Stereo/Radio	1	17
	- CFL	1	10
	- Ventilator	1	30
#	*Room 3*		
	- Incandescent	1	100
	- Stereo/Radio	1	17
	- CFL	1	10
	- Ventilator	1	30
#	*Laundry Room*		
	- CFL	1	14
	- Fan	1	70

-	Vacuum machine	1	1,400
-	Washing Machine	1	920
-	CFL	1	14
-	Ventilator	1	30

Monastery's Abbot House

-	CFL (corridor)	1	14
-	FL short (store room)	1	18

\# **Guest monk room**

-	FL short	1	18
-	CFL	1	15
-	Heater	1	1,500
-	Kettle	1	2,400
-	Foot Massage machine	1	80
-	Massage Chair	1	80
-	CFL	1	14
-	Ventilator	1	30

\# **Abbot room**

-	CFL	1	15
-	CFL	1	14
-	Heater	1	2,000
-	CFL	1	14
-	Ventilator	1	30
(In his cave)			
-	Heater	1	2,000
-	Halogen (Desklamp)	2	24

Workshop building

-	FL (long)	2	36
-	FL (long)	6	36
-	Electric Mechanical Device (L.S.)*	1	3,000

-	FL (short)	2	18
-	Sewing Maching 1	1	110
-	Sewing Maching 2	1	123
-	FL (long)	2	36
-	CFL	2	15
-	Kettle	1	2,400

Garage

-	CFL	2	15
-	Heater	1	1,500
-	Kettle	1	2,400

Ablution Block

-	Water Pump	1	1,600
-	Kettle	1	2,400
-	Washing Machine	1	920
-	CFL	1	15
-	Incandescent	1	60
-	FL (toilet)	1	36

Toilet for guests

-	CFL (Male)	3	14
-	CFL (Female)	4	14

Bioseptic Tank

#	System 1			
	-	Air pump	1	230
	-	Water pump	1	1,300
#	System 2			
	-	Air Pump	1	210
	-	Water Pump	1	1,300

* Electric Mechanical Device (L.S.) – there are many electric mechanical devices in the workshop but it is not necessary to describe all of them, according to Ajahn Brahmali, only a few are used at the same time and the electricity consumption could be approximately estimated equals to 3,000 W per hour.

3.2.7.2 Building Envelope options

General recommendation to the buildings where thermal insulation needs to be addressed as followed (Kreith and Goswami 2007):

- Addition of thermal insulation – installing thermal insulation material on ceiling, wall etc.
- Replacement of windows – using more energy efficient windows
- Reduction of Air Leakage – estimating and optimizing the balance of air flow-in and flow-out

However, the Buddhist monastery generally ignores these techniques due to a lack of planning in building construction and also having not used much of air conditioners and heaters.

3.2.7.3 Electrical Equipments

This includes office equipments and pumping systems. The latter consists of motor which normally consumes high power. Usually, recommendations given in this area points out the availability of energy efficient equipments. Therefore, purchasing more energy efficient equipments should be aware when any of them is needed (Kreith and Goswami 2007). Furthermore, following manuals and specifications of electrical equipments can reduce energy consumed ineffectively according to overusing the equipments.

3.3 Renewable Energy Resources

Renewable energy resources at the site (the monastery) must be assessed before the implementation will be implemented. Although RETs are defined as that composed of conventional hydroelectricity, wave, tidal, geothermal, biofuel, solar, and wind, but not all of them can be utilized since renewable energy issues we are discussing here is focused on the small-scale or residential or institutional system (considered as size of monastery). Therefore, only solar, wind and biofuel (biogas) are discussed at this stage, whereas others can be reconsidered when time or technology in the future will make them more appealing in a sense of costing and appropriate technology approach.

3.3.1 Wind Energy

Wind energy has been the first source that the monastery would like to make use of at the first place. It was in 2007 when Ajahn Brahm originally came up with the idea of installing wind turbine at the site. Although in fact, he wanted to install it at the retreat center – a meditation practice place; about 1 kilometer away from the monastery, but with an assumption that there is no difference in wind data, it is worth considering wind energy application. This is worthwhile because not only the monastery would like to do so but it is also according to its most successful as much as the most progressive renewable energy technology in energy market due to its cost competitiveness compared to other renewable technologies. Wind turbine, if wind speed is high and steady enough, is a good choice for the monastery. However, in order to maximize its efficiency, turbulence effect must be taken into account. This has led to a main reason why the wind energy has not been proceeded at the monastery since many trees must be cut down. Moreover, noise pollution should be taken into account so as to assure that the purpose of the retreat center built in a secluded spot uphill in a middle of forest; would have been achieved.

3.3.1.1 Method

Similar to other countries, Australia has a significant meteorological database available, however, the provided data need to be evaluated since the location of the site and the meteorological measuring stations are not the same, besides, normally the anemometer mounted on the pole at the station are put at 10 m. above the ground (BOM 1997) which is not the height that the wind energy conversion system installed in general. Therefore, this will roughly estimate the wind condition at the site.

For this instance, two stations are used to evaluate the possibility of the wind turbine installation: Karnet station and Dwellingup station.

- Karnet station is located about 11.1 km away from the site;
    - Average wind speed = 3.53 m/s (at the height of 10 m.)
- Dwellingup station is located about 41 km from the site
    - Average wind speed = 4.61 m/s (at the height of 10 m.

These data from the two stations then must be converted to compare to the reference wind resource assessment. According to NREL's Wind resource assessment handbook, the windspeed at above 7 m/s is suitable for most wind turbine applications with the windspeed of 6.5 m/s can be used for wind energy development using tall turbines (e.g., 50 m. hub height) while the wind speed less than 5.1 m/s is not suitable for wind energy development (see Table 3.4). In order to compare with these guideline wind data from Karnet and Dwellingup therefore have to be extrapolated to a reference height (30 m. in this instance) by the following power exponent function:

$$v_2 = v_1 \times \left[\frac{z_2}{z_1}\right]^{\alpha}$$

where

v_2 = the unknown speed at height z_2

v_1 = the known wind speed at the measurement height z_1

α = the wind shear exponent

Example:

Wind speed at the Karnet station = 3.53 m/s at the height of 10 m.

Therefore, at the height of 30 m. the windspeed is:

v_2 = 3.53 m/s x (30 m./ 10 m.)$^{0.143}$

α = 0.143 as NREL's recommendation for a well-mixed atmosphere over flat, open terrain, however Table 3.5 provides the various values of α if the measurement location is known adequately.

v_2 = 3.53 m/s x 1.17

v_2 = 4.13 m/s

By the same token, the wind speed at Dwellingup has been found which is:

$v_{Dwellingup}$ = 5.39 m/s

Table 3.3: Average wind speed at Karnet and Dwellingup

Station	Average Wind Speed (m/s) at 30 m. height											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Karnet	4.66	4.67	4.32	3.72	3.39	3.39	3.63	3.95	4.31	4.56	4.57	4.40
Dwellingup	6.12	6.03	5.64	4.93	4.80	5.06	5.03	5.05	5.25	5.40	5.70	5.78

Table 3.4: Classes of Wind Power Density (NREL 1997)

Wind Power Class	30 m (98 ft) Wind Power Density (W/m2)	Wind Speed m/s (mph)	50 m (164 ft) Wind Power Density (W/m2)	Wind Speed m/s (mph)
1	≤160	≤5.1 (11.4)	≤200	≤5.6 (12.5)
2	≤240	≤5.9 (13.2)	≤300	≤6.4 (14.3)
3	≤320	≤6.5 (14.6)	≤400	≤7.0 (15.7)
4	≤400	≤7.0 (15.7)	≤500	≤7.5 (16.8)
5	≤480	≤7.4 (16.6)	≤600	≤8.0 (17.9)
6	≤640	≤8.2 (18.3)	≤800	≤8.8 (19.7)
7	≤1600	≤11.0 (24.7)	≤2000	≤11.9 (26.6)

Table 3.5 Wind speed parameters for calculating a vertical profile (Tiwari and Ghosal 2005)

Types of Terrain	Roughness Class	Exponent (α)
Water areas	0	0.01
Open country, few surface features	1	0.12
Farmland with building and hedges	2	0.16
Farmland with many trees, forests, villages	3	0.28

3.3.1.2 Result

From Table 3.3 it shows the average wind speed in each month of a year. In general, the wind speeds are relatively low which are represented by the overall average wind speed of each station:

v_{Karnet} = 4.13 m/s - NREL's Class 1 (See Table 3.4)

$v_{Dwellingup}$ = 5.39 m/s - NREL's Class 2 (See Table 3.4)

Therefore, wind energy resource at the monastery is <u>not suitable</u> for wind energy development by this consideration.

3.3.2 Solar PV

Figure 3.9 shows average daily solar exposure annual indicated by different colors throughout Australia . The monastery locates in a region where the average daily solar exposure equals to 21 Megajoules per square metre. However, at this stage, other methods to access solar energy information are discussed in order to find more details and seasonal effects.

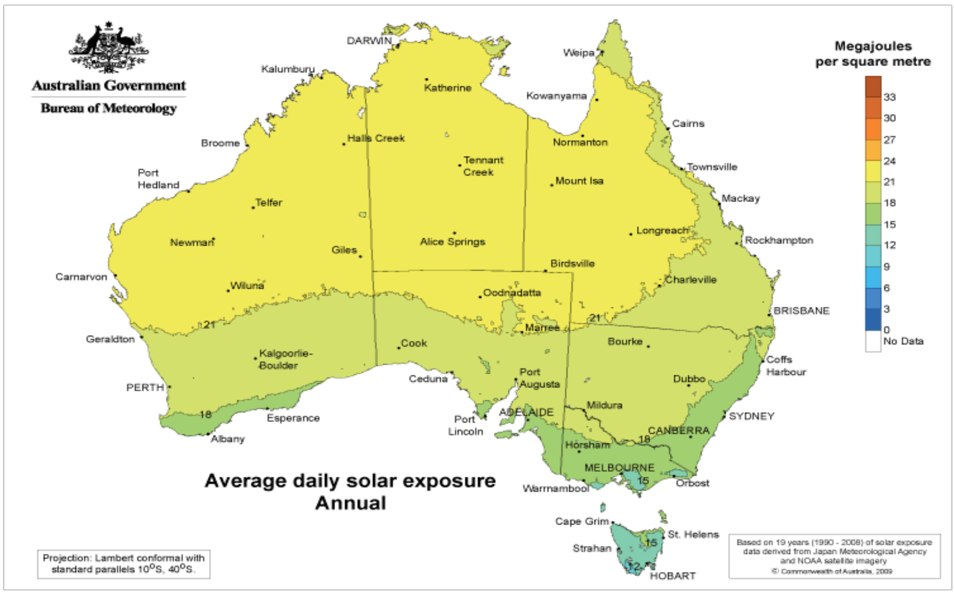


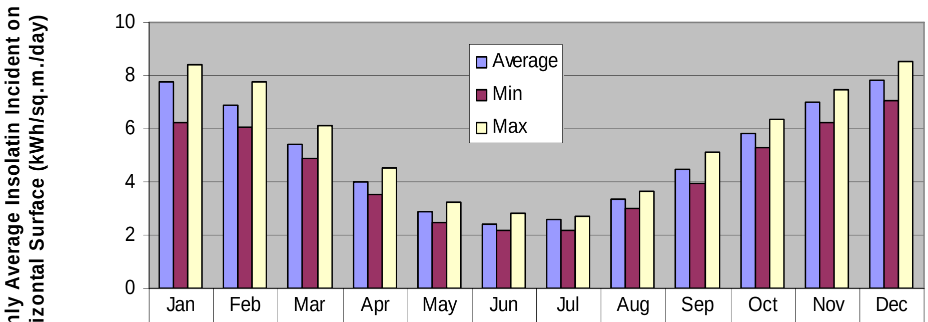
Figure 3.9: Australia's Average daily solar exposure: Annual (BOM 2008)

3.3.2.1 Method

Solar PV potential can be extracted from solar energy resource at the site. Prior to the installation of solar energy application, it is vital to predict both the demand and the solar energy available, coupled with their variability. Understanding demand of energy consumption and supply of energy source, it is adequate to design the system. Ideally, as many as possible years of measurements should be performed in order to predict pattern of energy available accurately, however, this is rare. So, the required data must be estimated from meteorological data available either a) from the site, or b) from some 'nearby' site that has similar irradiance, or c) from an official solar atlas or database (Twidell and Weir 2006). Nevertheless, under an assumption that a consideration of harnessing renewable energy for Buddhist monastery should be simple, site measurement in which expensive measurement devices such as Pyranometer or Pyrheliometer (Duffie and Beckman 1991) have to be omitted. In choice b) data from nearby site, even though, it could be available in some sites but in most cases, it needs contacts and permissions from authority which is rather more complex than that of choice c) in comparison. This leads to the approach of this thesis to access data using NASA satellite measurement. This will also benefit users who use HOMER and RETSCREEN computer-based project analysis software as a correlation between them makes input data process more convenient (NASA 2010a). Note that it has been stated in the website that satellite-derived value data is slightly different to ground site data sets. Accuracy of data could be more accurate than ground measurement data. All this because ground measurement data, without specialized high quality research data monitoring program, can obtain uncertainties from calibration drift, operational uncertainties, or data gaps (NASA 2010b).

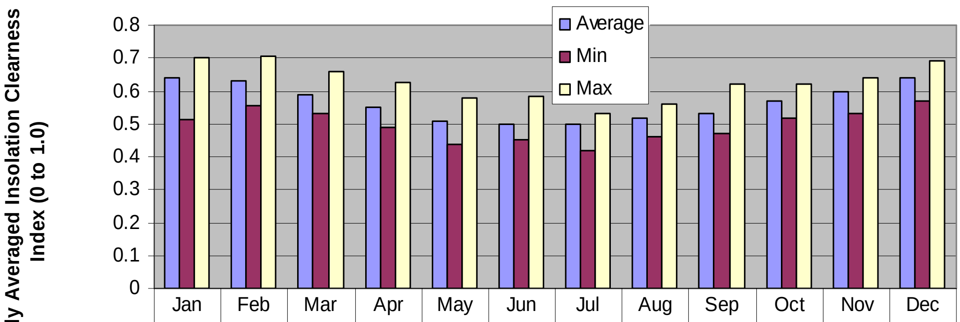
3.3.2.2 Result

From NASA website, having identified and filled out the latitude and longitude of the monastery gives the user's interface showing various parameters ready to be used, however, in this case, only Solar Geometry Information: Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications: Insolation on horizontal surface and Insolation clearness index are needed. These data are put in tabular forms as shown in Figure 3.10 and Figure 3.11 (and also the user's interfaces from the website can be found in Appendix)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	7.78	6.91	5.44	3.98	2.88	2.42	2.58	3.35	4.46	5.85	6.99	7.84
Min	6.22	6.08	4.90	3.54	2.45	2.20	2.19	2.98	3.92	5.32	6.22	7.06
Max	8.40	7.74	6.09	4.54	3.23	2.83	2.73	3.65	5.13	6.38	7.48	8.55

Figure 3.10: Monthly averaged insolation incident on horizontal surface (kWh/m2/day)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0.64	0.63	0.59	0.55	0.51	0.5	0.5	0.52	0.53	0.57	0.6	0.64
Min	0.51	0.55	0.53	0.49	0.44	0.45	0.42	0.46	0.47	0.52	0.53	0.57
Max	0.70	0.71	0.66	0.63	0.58	0.59	0.53	0.56	0.62	0.62	0.64	0.69

Figure 3.11: Monthly averaged insolation clearness index (0 to 1.0)

From the values in Figure 3.10 and Figure 3.11, this can be concluded that the site at the monastery is a good site for solar energy because the clearness index is relatively high (0.6 – 0.7) although in winter when rains, clouds, fogs and even smogs may be a cause that decreases the clearness index values (See Meteorological data in Appendix). Having low clearness index, solar radiation is quite low in winter accordingly, whereas in summer the values is good.

3.4 The installation of Solar PV System at the Monastery

In February 2010, the 4.18 kW system was installed on the roof of the workshop building at the entrance of the monastery near the grid as shown in Figure 3.12.

Figure 3.12: 22-190 W (4.18 kW) Solar PV system installed at the monastery

3.4.1 System design

The main criteria of the system set out for the monastery is to maximize the benefit of the Australian renewable energy technology incentives: Feed-in Tariff, also known as Renewable Energy Buyback Scheme (Synergy 2010) and the REC (Renewable Energy Certificate) (Rossiter and Singh 2006), therefore, the upper limit of 5 kilowatts system have been considered. Due to grid connection system, the design needs not to deal with load demand compared to the stand-alone power system where load demand must be taken into account as it is a main factor to size the system.

Prior to the installation, the system design aimed at 4.9 – 5.0 kW solar PV system to maximize the benefit from the Synergy's REB scheme, however, According to Ajahn Brahmali, the installer company (Renewablelogic Company) was told by Western Power that the transformer at the site was too small. It was a 10 kW transformer (See Figure 3.13). This indicates that the load at the monastery is very small and therefore can create a problem with the reverse flow of power towards the grid. This is a problem which is prevalent on the fringe of the metropolitan area where demand is lower. Within the metro area, energy flowing from small grid connected energy generating systems will likely be consumed by neighboring properties before it reaches the transformer. In fringe areas like Serpentine or Jerrahdale (the suburb where the monastery locates in), properties often have their own transformer (as is the case at the monastery) so that the power produced will not be consumed by neighboring properties. Consequently, the voltage in the area will rise and may cause the inverter to shutdown if the voltage rises outside the preset limits of the inverter. In a worse case the increased voltage has the potential to damage electrical equipment on the property. This situation is most likely to occur in the middle of the day when the output of the system is at its highest and demand at the property is at its lowest.

Figure 3.13: 10 kW transformer at the entrance of the monastery

Other contributing factors are the size and length of the cables feeding the property. An investigation into both of these revealed the cables where large (16mm) enough and short enough (approximately 50 m) so as not to contribute to the problem.

The system consists of 22 x 190W monochrystaline modules connected to a 5kW SMA 5000TL inverter with dual maximum power point tracking (See Figure 3.14), meaning the inverter has two inputs which will monitor the input voltage and current and find the best combination of each to produce the highest amount of power. The modules were connected in two parallel strings of 11 modules providing an open circuit voltage of 480V and a short circuit current of 5.2 amps. The array was mounted flush to the roof of the workshop on an approximately 25 degree pitch facing almost true North (as in Figure 3.12).

Figure 3.14: PV Inverter Sunny Boy 5000TL

3.4.2 Renewable Energy Certificate

Solar PV and other renewable energy system are known to be more expensive than the conventional system. Without rebates or incentives assisted from governments the systems are less competitive in energy market. Renewable Energy Certificate (REC) is one of the incentives designed to help reducing the high initial cost of installation. REC can be created (via registered persons) by electricity generation using renewable energy technology (Rossiter and Singh 2006). From Table 3.6, 225 RECs incurred in this quotation has been calculated basing on the 4.9 kW system (from the original proposal, for 4.18 kW system it should be 211 RECs). This includes the contribution from solar credits (with multiplier = 5 for the system less than 1.5 kW). The installer company has bought RECs from the monastery at $25 per REC; however, the company will trade these RECs at higher price (> $25).

Table 3.6: Cost of the 4.18 kW Solar PV system at the Bodhiyana Monastery

Materials	Amount	Unit Cost	Total
Sungrid SG-190	22	650.18	14,303.96
Aurora 5 kW	1	3,765.83	3,765.83
5 kW Installation	1	3,960.00	3,960.00
5 kW BOS	1	2,358.04	2,358.04
REC	225	- 25.00	- 5,625.00
		EX. GST	**18,762.83**

3.4.3 Before and After the installation

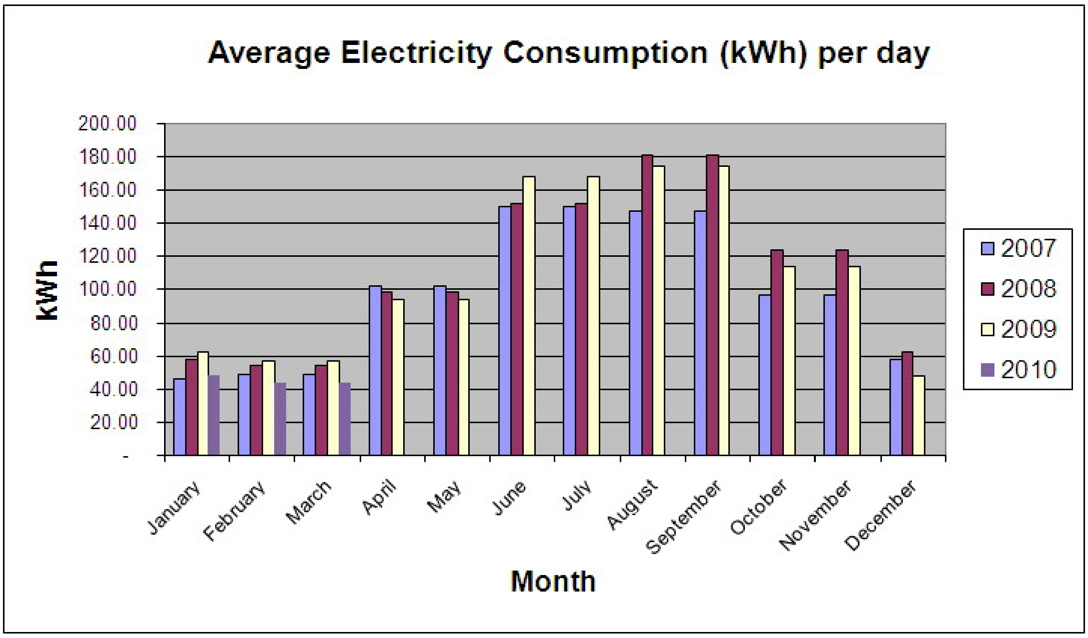


Figure 3.15: Average daily electricity consumption (kWh) per day throughout a year from 2007 to 2010

Figure 3.15 shows the average daily electricity consumption per day from 2007 to 2010. As mentioned that the solar PV system was installed in February 2010. At this stage, with the bill received until the end of March, therefore only the consumption in February and March 2010 can be compared year 2007, 2008 and 2009. It is obvious that in February and March 2010 the consumption is less than those years before 2010. Although this can be explained in two ways: the overall consumption has been reduced (residents consume less than usual) and the solar PV system has reduced the overall consumption, but the latter seems more reasonable explained by the trend of energy used tends to increase from 2007 to 2009. Therefore, this can be concluded that after the solar PV was installed in February 2010, the electricity bill has been reduced. Regarding REB, according to Ajahn Brahmali, since load demand is far more than the electricity generated by the solar PV system therefore the power output from solar PV system is used up with no excess power for sending back to the main grid.

3.5 Guidelines of RETs Development for Buddhist Monastery

In contribution to other monasteries, this section has provided guidelines of the consideration of renewable energy development.

3.5.1 Before going straightforward to RETs, the options of energy efficiency as stated in section 3.2.7 should be addressed. These options can also reduce your electricity consumption bill significantly.

3.5.2 In order to do as in 3.6.1, energy audits must be conducted. Firstly, collect all energy bills in last 24 consecutive months, then plot out all collected data into a graph showing a relation of daily energy consumption and months of a year. This will identify some problems of the energy consumption either from the residents or electric appliances.

3.5.3 Note that if grid connection is available, it is better to connect to the main grid because it is more economic unless the monastery wants to participate in a clean energy generation campaign.

3.5.4 However, if RETs are still in need, renewable energy resource assessment must be conducted.

Guideline for wind energy resource assessment

3.5.5 For wind energy, wind measurement should be conducted. Wind measurement device (anemometer) should be installed at the height where the turbine will be installed; otherwise, the height of 30 m is commonly referred as a reference height. The height of 6 to 15 m can also be used as it is a typical airport anemometer height (NREL 1997).

3.5.6 The characteristic of topography of surrounding areas are substantial for wind energy development. The ideal surrounding area is flat and unobstructed whereas the terrain where surrounded with buildings and trees can influence on the wind flow which should be avoided or used with caution.

3.5.7 In some cases, wind data at which it can represent the wind data at the proposed site, then it could be used. At the Bodhiyana Buddhist monastery site, the BOM station locating at 11 and 41 km from the site are used.

3.5.8 The ideal wind data contains wind speed and direction at every 10 min all year round. It is useful because if the variation of wind speed and direction can be evaluated, then the relationship between load demand and load supply is known giving a chance for energy management. (Note: Temperature and atmospheric pressure are omitted in this guideline for the sake of simplicity; however, wind measurement requires these two parameters to calculate the variation of energy density of wind due to temperature and pressure).

3.5.9 The ideal wind data in 3.5.8 will be used in a computer-based program for example HOMER (freely available on its website http://homerenergy.com/) otherwise, it is relatively inconvenient for hand calculation.

3.5.10 To find the power output per year, we can roughly estimate it using the equation:

- Power available in wind,

  $P \text{ (watt)} = \frac{1}{2} \rho A v^3$

  Where; ρ = the density of the air, kg/m^3

  A= the cross-sectional area of interest, m^2

  v = the wind speed, m/s

  Note that the maximum power output extracted from this equation has an upper limit dependent on the theoretical limit to aerodynamic efficiency $C_p max = 59.3\%$ (Boyle 2004).

- However, a rough initial estimate of the electricity production (in kilowatt-hours per year) can be achieved by this equation (Beurskens and Jensen 2001; Anderson 1992; EWEA 1991):

  Annual electricity production (kWh per year) = $K V_m^3 A_t T$

Where: K = 3.2 (a factor based on typical turbine performance characteristics and an approximate relationship between mean wind speed and wind speed frequency distribution

V_m = the site annual mean wind speed in m/s

A_t = the swept area of the turbine in m^2

T = the number of turbines

Guideline for solar energy resource assessment

3.5.11 For solar PV, solar energy measurement can be conducted using Pyranometer. However, commonly the device is rarely used due to its expensiveness and the availability of solar radiation data throughout the world using the NASA's website (http://eosweb.larc.nasa.gov/sse/). This is not including those available data collected by the meteorological department in each region. Note that the solar radiation does not vary significantly within immediate vicinity compared to wind data.

3.5.12 Similar to wind energy, the ideal solar radiation data in 3.5.11 will be used in a computer-based program for example HOMER.

3.5.13 Likewise, the rough estimate can be achieved simply by solar radiation multiplies by area required (depending on load demand for example 5 kW system of the Bodhiyanan monastery, in case the system is off-grid system, sizing of PV array is more complex which brings in more derating factors).

3.5.14 The orientation of the PV array, typically faces north if it is in southern hemisphere or south if it is in northern hemisphere. The tilted angle is approximately set at the angle of latitude of the location of the system.

Accessories

3.5.15 In general, the power output of the wind and solar PV is direct current (DC), and then the inverter is needed to convert DC into AC for electronic appliances used in general.

3.5.16 Size of cables is also important. If long distance connection between the system to loads, then size of cable must be adequately big to compromise losses incurred due to the length of the cable.

Chapter 4: Buddhism and Renewable Energy Technology

In this chapter, the relationship between Buddhism and renewable energy technology is discussed. Two ways of consideration are brought up to discuss in further detail in this chapter: Buddhism in response to Energy Efficiency and Renewable Energy Technology respectively. Whilst E.F. Schumacher's Buddhist Economics and a simple of Buddhist life concept are for Energy Efficiency, an appropriate technology is for Renewable Energy Technology.

4.1 Prologue

We are now at the stage that we aware of the threat of climate change effects. We know that the climate change catastrophic damages will severely affect the global environment and thus affects us. But with its slow and ongoing deterioration of the effects, it can be an obstacle in a sense that human nature needs fear or feel of danger before reacting to it.

To decelerate a process to the catastrophe, GHGs emissions and productions must be substantially reduced. This needs the international cooperation in setting a target to bring down the pollutants in the atmosphere and slowing down the polluters an attempt to move forward without thinking and caring of the ecological effects. Kyoto and Copenhagen summits have shown that we know what is occurring and at the same time, shown that we have not achieved the international cooperation just yet.

To put all responsibilities to those heads of states and policy makers may be not fair, because we are all parts of the inappropriate energy consumption. We are emitting GHGs to the environment either intentionally or unintentionally. Incorporating various improper conducts towards the use of finite fossil-based energy makes up a collective improper conduct from a small community to a bigger one, to a country and therefore to the world. Likewise, a proper conduct from a small scale can affect the wholesale scale collectively. This is why the concept, 'small is beautiful' should be addressed as a nature should as well be the decentralized ownership of public property (Schumacher 1999). In his book (1999), Buddhist economic has been mentioned. Some quotes relevant to the Buddhist economic are (1999, 33):

> *"[A modern economist] is used to measuring the 'standard of living' by the amount of annual consumption, assuming all the time that a man who consumes more is 'better off' that a man who consumes less. A Buddhist economist would consider this approach excessively irrational: since consumption is merely a means to human well-being, the aim should be to obtain the maximum of well-being with the minimum of consumption….Modern economics, on the other hand, considers consumption to be the sole end and purpose of all economic activity."*

and (1999, 34)

> *"It is clear, therefore, that Buddhist economics must be very different from the economics of modern materialism, since the Buddhist sees the essence of civilization not in a multiplication of want s but in the purification of human character. Character, at the same time, is formed primarily by a man's work. And work, properly conducted in conditions of human dignity and freedom, blesses those who do it and equally their products."*

and (1999, 18)

> *"Ever bigger machines, entailing ever bigger concentrations of economic power and exerting ever greater violence against the environment, do not represent progress: they are a denial of wisdom, wisdom demands a new orientation of science and technology towards the organic, the gentle, the non-violent, the elegant and beautiful."*

The latter quote has accommodated the coming of new era of RETs while energy efficiency can best fit for the concept of simplification of life. However, before discussing further details in other aspects, it is worth considering what was said in the classical economic-related book ‘Small is beautiful’ by E.F. Schumacher in two main points: Buddhist economics and intermediate technology (aka appropriate technology).

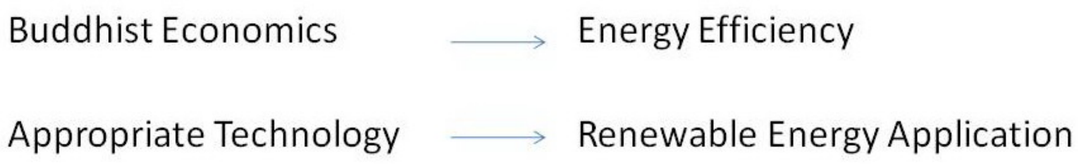


Figure 4.1: the relationship of energy and Buddhism in this paper

4.2 Buddhist Economics

Among the Buddha’s teachings ‘the Noble Eightfold Path’ including: Right Understanding, Right Thought, Right Speech, Right Action, Right Livelihood, Right Effort, Right Mindfulness and Right Concentration, Schumacher (1999) mentions Right Livelihood as a core of the Buddhist economics. Right Livelihood, in other words, means ways to do for living within the righteousness. By its real purpose from Buddhists’ point of views, Right Livelihood restrains immoral action. In order to do that, Buddha identifies five forbidden careers to be avoided consists of: dealing in weapons, in living things, in meat production, in poison, and in intoxicants. This is because all five livelihoods can bring harm to other lives. Right Livelihood is in accord with other two paths which are Right Speech and Right Action to make up the division of moral discipline (Bhikkhu Bodhi 2010).

The reason he (1999) picks up this path, perhaps, he sees the point ‘not to bring harm to other lives’ as a sustainable development tool, he then aims at arguing the mainstream of economic thought at that time, as the classical western economists sees labors simply only as an element of cost. Conversely, labors would see "*to work is to make a sacrifice of one's leisure and comfort, and wages are a kind of compensation for the sacrifice" (1999, 33).* Schumacher argued this kind of attitude would not sustain the development since the classical western economics prioritizes product and profit as the first objective, whereas a well-ordered society was ignored. In fact, the function of society should assist in developing the character of individuals (Corbett 2009). Individualism in Buddhism is very important. The main reason why one needs to practice Buddhism is to separate oneself from the dependence of any sorts of things, i.e. less dependency less suffering (The Venerable Prayudh Payutto 2010). However, it is impossible to be independency from everything since we need food, cloth, home, and medicine; to keep alive and to do good conduct but one must develop oneself at all time and working is a part of living but not all.

In term of consumption, the decisions of a conventional economics and a Buddhist economics; to make use of scarce resources are different. While western economics wants to use the resource as much as possible to maximize the productions and profits meaning the more consumption the happier, Buddhist economics, in the other hand, questions it whether we need to consume that much to make us happy. Schumacher answers that people living in their communities and doing meaningful work are happier (Zetland 2009). This accommodates the concept 'simple living', also known as 'voluntary simplicity', the lifestyle that consumes when need not when want, only to sustain life and to reduce personal ecological footprint.

In regard to energy consumption, this kind of attitude is essential as a pre-requisite condition for anyone to understand that inappropriate energy consumption potentially affects or harms other lives. Therefore, this is a door open to energy efficiency practices and renewable energy technology to come in and take the opportunity to alleviate environmental damages from the climate change.

4.3 Intermediate Technology – Appropriate Technology

Intermediate technology is another point made by E.F. Schumacher inspired by Mohandas Gandhi to provide a chance for poverty in committing to a technology. The idea has originally come from the inequity in wealth between developed and developing countries where the poor are getting poorer and the rich are getting richer. The reason alleged to this deviation is the aim of conventional economics in which it sees economic growth and an increasing figure of GNP as a tool to alleviate unemployment and poverty. Schumacher (1999) points out that the growth, in fact, increases a gap between the rich and the poor because he sees a wealth incurred has been channeled to only a small group of the rich rather than dispersed to the poor. Given those arguments, he concludes that all efforts in a development should be decentralized to the poor in locals instead of central to only urban areas. With technology needed in developments, the intermediate technology would fit the requirement, cable to meet the purpose of the technology to drive the development contributing to the local needs and skills within a rational cost (Hansgate 2008). In contrast to a modern, high efficient but high cost technology, an intermediate technology, albeit more expensive than conventional technology, is more efficient than conventional technology and affordable to poor people. Then, the technology serves the task to produce more products but helps in minimizing social dislocation. More concrete actions to this concept, the Intermediate Technology Development Group was born in 1966 (later renamed to Practical Action) lending itself as an advisory centre to promote the use of efficient, labour-intensive techniques suitable for local which later triggered the appropriate technology movement. The term 'intermediate technology' and in recent times more commonly 'appropriate technology' can be used interchangeably to explain the technology which incorporates concerns of impact on environment and society, this is also referred to 'appropriate and sustainable technology' (iCAST 2010).

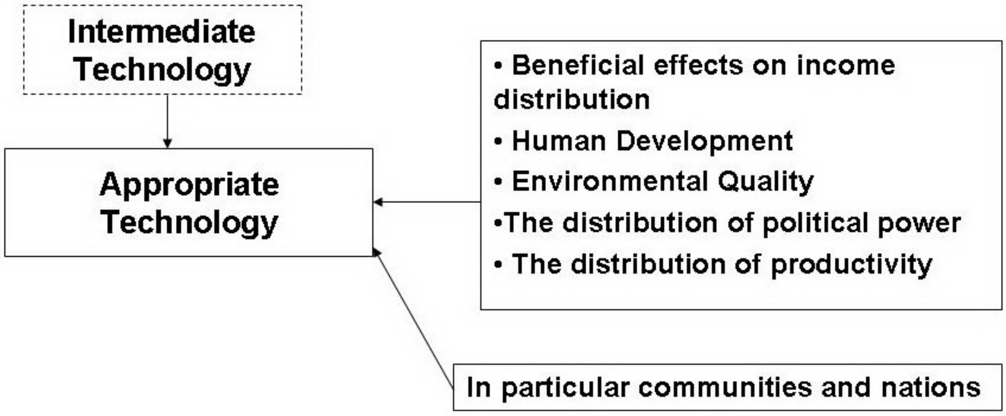


Figure 4.2 : Factors of Appropriate Technology (Villageearth 2010)

Appropriate Technology nowadays has gained more meaningful, capable to be used not only for the poor in rural areas but for those in a modern world in developed countries. Apart from decentralization, appropriate technology has also associated with other factors, for example in the U.S. these comprise concerns of the environment, energy and resource crises, local employments, imported technologies and materials, local development and cultural traditions (Villageearth 2010). It is also interesting to see its meaning is narrowly mentioned to green movement and renewable energy application, for instance, the Appalachian State University in Boone, New York offers an undergraduate degree in appropriate technology which encompasses an energy efficiency and renewable energy application to engineering, including the design and construction of solar-powered buildings, drafting, design, woodworking, metalworking, computer literacy, architecture and green construction (Schneider 2008). All this pinpoint the potential of the application of energy efficiency and renewable energy as an appropriate technology.

4.4 Buddhism and Renewable Energy Technology

4.4.1 Literature Reviews

Literature reviews show some difficulties in seeking for the material in relevant to the relationship between RETs and Buddhism due to:

- this approach could be only a minority of people interesting in writing documents about religion and RETs
- most of those articles found on internet have mentioned RETs as an option to fight Climate Change, this is because Buddhists see Climate Change as a consequence of what we have done which conforms to the law of karma. Therefore approaching RETs as a tool in response to Climate Change, this mindset could be used.

Nevertheless, Kim Kyung-Nam has written the article titled 'is Buddhism a renewable energy?' this article is about the relationship between RETs and Buddhism using biofuel technology by saying that one aspect of Buddhism - Samsara or transmigrationism or a belief that we die and we will be born again, which can be used to explain the utilization of biofuel using algae (Kyung-Nam 2009).

He (2009) says that

"Buddhism's transmigrationism says that with bad karma, human beings can be born again as animals and that animals can be reborn as human being with good karma. Energy's transmigrationism says carbon dioxide can be born again as algae and the algae reborn as carbon dioxide passing through biodiesel and automobiles.
As Buddhism' karma is the driving force for outer form conversion, solar energy and engineering technology are the driving force for the transformation of algae into bioenergy."

This needs to be emphasized again that the belief of a law of karma is a driving force for people's death and birth, in comparison, solar energy and engineering technology are the driving force for the transformation of algae into bioenergy.

A driving force is very important since religion is based on belief and it is a internal driving force of people for any action so if we believe in doing things as a cause of the effects, then if we realize that if we keep doing this it will affect others, then we have to stop. This is the way Buddhism responds to Climate change that we are facing a consequence of inappropriate energy consumption. In responding Climate Change, RETs have been used as a tool to replace the use of fossil-fuel based technologies. As belief is able to direct thought and action, one way of the introduction of RETs, in countries where worship dragons, A dragon has been used as a symbol for renewable energy (See Figure 4.3) because it is believed that dragon represents the primal forces of nature, religion, and the universe. It is associated with wisdom and longevity (Stanley, Loy, and Dorje 2009).

Figure 4.3: The author of the book 'A Buddhist Response to the climate emergency' sees dragon as an appropriate symbol for renewable energy (Stanley, Loy, and Dorje 2009)

The main keys or the driving forces of the movement for renewable energy advocates throughout the world consist of Climate Change and Uncertainty of oil prices. RET then play a major role in responding the threat from both driving forces as a result of its less damage to nature and the promotion of the use of local sources of energy.

Driving forces		Action
• Climate change	→	Environmental Protection
• Uncertainty of Oil prices		
– Energy Security	→	Use of local sources of energy

Figure 4.4: Driving forces and Actions in relation to energy

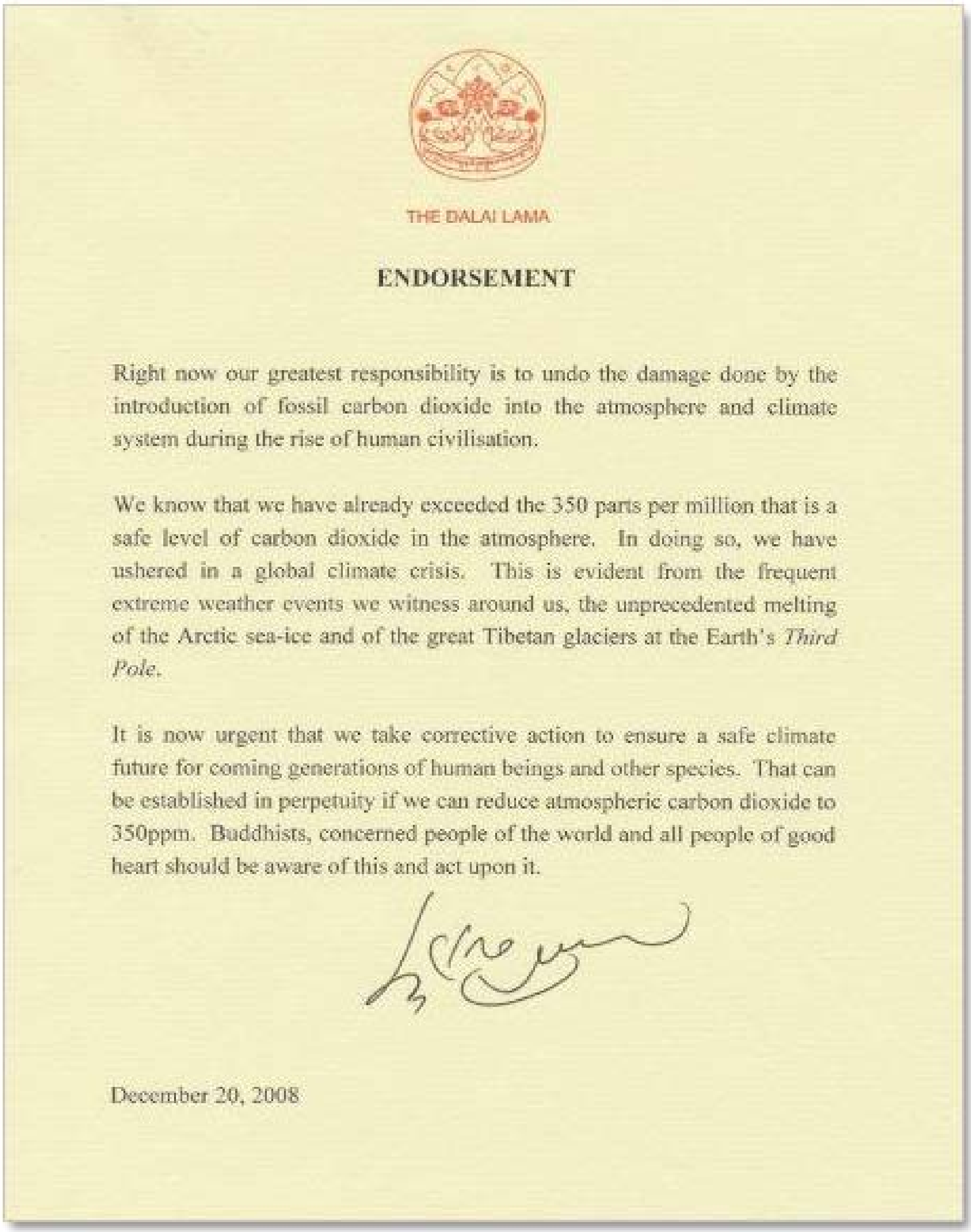
4.4.2 Buddhism at a glance

Buddhism or 'Bodhi' means awakening. So, what do we need to awaken from? We need to awaken from Avidya. What is Avidya? Avidya is 'ignorance' meanings *"not seeing things as they really are, or failing to understand the reality of experience or the reality of life"* (www.paofatemple.org 2010). This is why we need education to know things. By the same token, in Buddhism we need to understand the truth of ignorance regarding one's own self. This is the fundamental cause of suffering. We ignore the truth that we do not have to rely on anything. All feelings: craving-desire, greed, ill-will, anger, hatred, envy, jealousy, pride and the whole lot, are all because we depend on something even for ourselves. So in conclusion, Buddhism teaches us to get away from dependency, this includes getting away from even Buddhism and the lord Buddha at last (Santina n.d.). Having said that, sometimes you find the texts explaining that Buddhists strive to enter Nibbana or Nirvana where there is no longer desire and suffering (Yeung 2003).

One that is considered one of the most important Buddha teachings is 'Noble Eightfold Path'. This is the way you do to be approaching to nirvana. It is composed of Right Understanding, Right Thought, Right Speech, Right Action, Right Livelihood, Right Effort, Right Mindfulness, and Right Concentration

The terminology of 'Right' can be explained in Buddhism as "a middle way". A middle way in Buddhist arena is important because on the day the lord Buddha enlightened, he found this approach. The Buddhist ancient script introduces the story that after the lord Buddha had been sacrificing or torturing himself with lots of painstaking methods in order to find the way to understand and to release himself from suffering, he almost died by those methods, then he realized that this ‘s not the way to enlighten because he could die soon. That night after a while when he was meditating focusing on what happened from inside, there was an angel came to play the instrument with three strings, the three strings were set differently; one had been tighten too much, one was too loose, and the other one was the right one. The angel played the three strings one at a time. The loosen one sounded awful, the tighten one ripped off, and the right one sounded alright. That night the lord Buddha realized this implication then integrated it with various things from his experiences and his internal understanding of natures with the special force from a very deep meditation which sharpened his thought even much more efficient. Then he enlightened and has become the lord Buddha for all Buddhists until now.

Having discussed about all of these issues, Buddhism and Renewable Energy Technology is common in term of ‘**appropriateness**’. In fact, appropriateness can be used for all aspects not only in energy issues, but this is emphasized because the problems we are facing nowadays are caused by the inappropriate energy consumption. A good example of what we are facing as a result of inappropriate energy consumption or not living in a right livelihood style is a threat of climate change. While mainstream of scientists think this is a threat for our future, likewise, Buddhism also use this chance to convince atleast its adherents to act against climate change by acting against inappropriate energy consumption, supporting environmental protection, and having a look at opportunities to use RETs to replace power generation from large CO_2 emitters like fossil-fuel based power producers (Ecological Buddhism 2009). Figure 4.4 show the agreement made by Dalai Lama in which he agrees that the allowable content of CO2 in the atmosphere should not exceed 350 ppm (www.ecobuddhism.org 2008).



THE DALAI LAMA

ENDORSEMENT

Right now our greatest responsibility is to undo the damage done by the introduction of fossil carbon dioxide into the atmosphere and climate system during the rise of human civilisation.

We know that we have already exceeded the 350 parts per million that is a safe level of carbon dioxide in the atmosphere. In doing so, we have ushered in a global climate crisis. This is evident from the frequent extreme weather events we witness around us, the unprecedented melting of the Arctic sea-ice and of the great Tibetan glaciers at the Earth's *Third Pole*.

It is now urgent that we take corrective action to ensure a safe climate future for coming generations of human beings and other species. That can be established in perpetuity if we can reduce atmospheric carbon dioxide to 350ppm. Buddhists, concerned people of the world and all people of good heart should be aware of this and act upon it.

December 20, 2008

Figure 4.5: This is an agreement and pronouncement from Dalai Lama showing that he supports a limitation of CO_2 at 350 parts per million per volume. He also asks his adherents to act upon this agreement (www.ecobuddhism.org 2008)

4.5 Concluding Remarks

At this point, this paper shows that every sector can help in promoting RETs including religious sector. Buddhism for example, can play a role in teaching and informing the fact of what is happening to our society, and our world regarding energy and environment. Several actions can be thought of in terms of energy efficiency as a simple life-style.

Buddhist monks can be an example for all of us but it does not mean that we need to do the same things as they do for living. But the key is to live appropriately so that we can develop our society while we can help to reduce environmental damage from inappropriate energy consumption and that's where the Buddhist term Right Livelihood can be useful. RET is an option of energy resource, anticipated to reduce GHGs emission from fossil-fuel based technology and to get ourselves away from the dependency of oil price uncertainty in long run. Installing the solar PV or wind turbine at the monastery can raise attention and awareness from public and that is a chance to provide information in many aspects for the final goal to see the term 'sustainable development' not just a good term but can become real.

Chapter 5: Conclusion

In conclusion, RETs for Buddhist monasteries are for two purposes: clean technology and rural electrification. In developed areas as same as the case study in Chapter 3 where electricity grid connection are available, RETs contributes to the monasteries by reducing the energy bills whereas in rural areas RETs plays important role in bringing up the quality of life for the residents in the monasteries. Chapter 2 shows some examples of rural areas in which they have gained benefits from the solar PV system in replacing the use of kerosene lamp. By the same token, solar PV, solar thermal, and wind turbine installed at the Poh Ern Shih Temple in Singapore has also illustrated the benefit from the electricity bills which have been expected to be reduced. More importantly, the Singaporean monastery has had attentions from Buddhists around the world as it represents the Buddhist society in response to the energy crisis as a result of dependency on fossil-fuel based technologies. This is significant in a sense of renewable technology as an appropriate technology. The term - 'Appropriateness', has played a major role in Chapter 4 which shows the way to approach the problems of mankind when dealing with energy crisis. Appropriateness can also be thought in the way to compromise the coexistence of renewable energy and fossil-fuel based energy. All this because we are in a transitional period from the fossil-fuel based technology to the non fossil-fuel based technology. While we need to promote the RETs, yet we need the fossil-fuel based technology. With mature technology and facilities provided, the fossil-fuel based technology is still essential to drive the movement of industry and the development of all societies but we also need to open the market to RETs as well. RET is an appropriate technology because if we implement RET project in a certain area it will also respond the needs of its vicinity:

beneficial effects on income distribution, human development, environmental quality, the distribution of political power and the distribution of productivity. In Chapter 1, in the aspect about the 'Limits to growth' principle, it shows the implication that we need to approach the energy crisis in both demand and supply side. In demand side, we need to care for the energy efficiency basis to try not to consume too much energy to not to waste energy. In supply side, RET is the energy for the sustainable development but the limit must be addressed to assure the future generation's energy requirement will be adequate without deteriorating environment.

The term 'driving force' is meaningful because it directs and motivates all of actions of us. This is why religion is so important in that the faith and belief can be considered as the internal driving force. This force makes people to do good things and bad things. One of good things to do for Buddhists is to make donation which later contributes to the introduction of RETs as it provides affordability to the monasteries in purchasing the systems.

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Appendix

Literature Reviews of Renewable Energy Technology in Buddhist Monasteries throughout the world

No.	Name of Buddhist monastery /temple (Country)	Motivation	Description	Financial Supporter (s)	Website Source (s)
1	Poh Ern Shih (Singapore)	Clean Tech.	This could be the best practice for the developed country's Buddhist monastery nowaday. It incorporates Solar Thermal, PV, and Wind and seeks ways to use Hydropower to power the monastery. On demand side, LED and CFL lamps show a significant saving in electricity consumption.	The Monastery	http://blog.cleantechies.com/2009/08/13/green-building-buddhist-po-ern-shih-temple-singapore/
2	Chiwong (Nepal)	Rural Electrification	The article written by Dennis Ramsey elaborates how the solar PV system has been installed at the monastery. Renewable Energy Development International (REDI) is a fund raising, design, and implementation organization founded by Dennis Ramsey in order to electrify the rural, mainly in Nepal and areas nearby using renewable energy technology.	REDI	http://www.homepower.com/view/?file=HP91_pg28_Ramsey http://www.redi-org.com/SunHorse.pdf

Literature Reviews of Renewable Energy Technology in Buddhist Monasteries throughout the world (Cont.)

No.	Name of Buddhist monastery /temple (Country)	Motivation	Description	Financial Supporter (s)	Website Source (s)
3	Pungmoche and Tumbuk (Nepal)	Rural Electrification	By Dennis Ramsey, two solar PV systems installed at different places almost in the same time. Another document (HP56) describes the upgraded project with another panel installed at the same both places.	REDI	www.redi-org.com/**HP45**.pdf www.redi-org.com/**HP56**.pdf
4	Traksindu (Nepal)	Rural Electrification	This article aims at raising fund for the solar PV installation at the monastery. REDI plays a dominating role in the area in converting solar energy for electrification at the monasteries. The document also mentions other monasteries installed by REDI including Chiwong, Tumbuk, Phungmoche, and Thupten Choling	REDI	http://www.redi-org.com/Traksindu.pdf

Literature Reviews of Renewable Energy Technology in Buddhist Monasteries throughout the world (Cont.)

No.	Name of Buddhist monastery /temple (Country)	Motivation	Description	Financial Supporter (s)	Website Source (s)
5	Ming Mongkol Buddha (Thailand)	Clean Tech. (Wind Turbine)	The monastery does not directly intend to install the turbines but it allows using its parking area to install the anemometer with 90 m. height tower. It also allows the wind farm implemented although, the wind towers will affect the vision of the big Buddha on the hill. This is important in terms of the cooperation showing an adaptation to the need of the technology and a care for a society. The project is part of the '5 temples 5 wind turbines project' in Phuket. Other four projects are not yet preceded.	Thai Government	http://www.phuketgazette.net/archives/articles/2009/article7743.html (in Thai) http://songkhlatoday.com/paper/34668 (in Thai)
6	Monasteries for the Dolpo people (Nepal)	Rural Electrification	The Dolpopas live between Nepal and Tibet can be considered the most remote area of the world with the harshest conditions. HLF has helped to install the solar PV systems for them.	HLF	http://hlf.org.np/uploads/clients/issues/0609378001205060188.pdf

Literature Reviews of Renewable Energy Technology in Buddhist Monasteries throughout the world (Cont.)

No.	Name of Buddhist monastery /temple (Country)	Motivation	Description	Financial Supporter (s)	Website Source (s)
7	Several monasteries in the remote Himalayas (Nepal)	Rural Electrification (Solar PV)	The project 'Solar Sisters' and 'Himalayan Gompa Lighting Project' implemented to help bring lighting to remote area.	HLF	http://www.hlf.org.np/index.php?id=2
8	The marma village community monastery, Bardarban (Bangladesh)	Rural Electrification	The document explains the survey trip to its destination. On the way to its project – 'the Gravity fed piped Water Supply Project; they found the Grameen Shakti (GS) solar PV installed at the village (20 km. from Bardarban). This implies the PV has been used in the area for a while since the project has a solar PV water pumping system as one of candidates.	GS	www.lged-rein.org/archive_file/FILD_VISIT_REPOR_III.pdf

Literature Reviews of Renewable Energy Technology in Buddhist Monasteries throughout the world (Cont.)

No.	Name of Buddhist monastery /temple (Country)	Motivation	Description	Financial Supporter (s)	Website Source (s)
9	Po Mean Chey Monastery, Two Buddhist temples in Pur Sat province, and Puthearam Buddhist monastery (Cambodia)	Rural Electrification	Solar Home Systems Demonstration implemented by Department of Energy Technique of Ministry of Industry, Mines and Energy (DET/MIME) funded by the Swedish International Development Cooperation Agency (SIDA)	SIDA	http://www.retsasia.ait.ac.th/booklets/Dissemination%20Booklets-Phase%20II/Full%20book-Cam.pdf
10	Thupten Choling monastery, (Nepal)	Rural Electrification and Environmental Protection	The last updated and biggest project REDI has initiated currently at the Thupten Choling monastery, in Solu Khumbu district, Nepal.	REDI	http://www.redi-org.com/Thupten/
11	Chaiyapoom Thai Forest Tradition Temple, (Thailand)	Rural Electrification	A group of Buddhists has gathered to give a wind turbine to a Thai forest tradition temple in Chaiyapoom province. None of informative details available but worth seeing the attempt to electrify the off-grid temple with wind energy.	Dana (Buddhists' collective offering)	http://www.chivit-itsara.com/forum/index.php?topic=5.0;prev_next=next#new

NASA's website - Solar Energy Information

(at the Bodhiyana Buddhist Monastery):

- **Monthly Averaged Insolation Incident on A Horizontal Surface (at the Bodhiyana Buddhist Monastery)**

SSE Homepage | Questions? | Find A Different Location | Accuracy | Methodology | Parameters (Units & Definition)

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy - Available Tables

Latitude -32.415 / Longitude 116.009 was chosen.

Geometry Information

Elevation: **291** meters
averaged from the USGS GTOPO30 digital elevation model

Northern boundary
-32

Western boundary
116

Center
Latitude **-32.5**
Longitude **116.5**

Eastern boundary
117

Southern boundary
-33

Show A Location Map

Parameters for Solar Cooking:

Monthly Averaged Insolation Incident On A Horizontal Surface ($kWh/m^2/day$)

Lat -32.415 Lon 116.009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	7.78	6.91	5.44	3.98	2.88	2.42	2.58	3.35	4.46	5.85	6.99	7.84

Parameter Definition

Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications:

Monthly Averaged Insolation Incident On A Horizontal Surface ($kWh/m^2/day$)

Lat -32.415 Lon 116.009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	7.78	6.91	5.44	3.98	2.88	2.42	2.58	3.35	4.46	5.85	6.99	7.84	5.03

Minimum And Maximum Difference From Monthly Averaged Insolation (%)

Lat -32.415 Lon 116.009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	-20	-12	-10	-11	-15	-9	-15	-11	-12	-9	-11	-10
Maximum	8	12	12	14	12	17	6	9	15	9	7	9

Parameter Definition

- **Clearness Index (at the Bodhiyana Buddhist Monastery)**

SSE Homepage | Questions? | Find A Different Location | Accuracy | Methodology | Parameters (Units & Definition)

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy - Available Tables

Latitude -32.415 / Longitude 116.009 was chosen.

Geometry Information

Elevation: **291** meters
averaged from the USGS GTOPO30 digital elevation model

Northern boundary **-32**

Western boundary **116**

Center
Latitude **-32.5**
Longitude **116.5**

Eastern boundary **117**

Southern boundary **-33**

Show A Location Map

Parameters for Solar Cooking:

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m^2/day)

Lat -32.415 Lon 116.009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	7.78	6.91	5.44	3.98	2.88	2.42	2.58	3.35	4.46	5.85	6.99	7.84

Parameter Definition

Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications:

Monthly Averaged Insolation Clearness Index (0 to 1.0)

Lat -32.415 Lon 116.009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average K	0.64	0.63	0.59	0.55	0.51	0.50	0.50	0.52	0.53	0.57	0.60	0.64	0.56
Minimum K	0.51	0.55	0.53	0.49	0.44	0.45	0.42	0.46	0.47	0.52	0.53	0.57	0.50
Maximum K	0.70	0.71	0.66	0.63	0.58	0.59	0.53	0.56	0.62	0.62	0.64	0.69	0.63

Parameter Definition

Back to SSE Data Set Home Page

Questions?

Responsible NASA Official: John M. Kusterer
Site Administration/Help: NASA Langley ASDC User Services (larc@eos.nasa.gov)
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