Energy Audit and Energy Management for Church Buildings in Hong Kong

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Executive Summary

The main objective of this research study is to investigate the energy audit process and energy management opportunities for church buildings in Hong Kong. The aim is to develop practical information and guidelines for promoting energy conservation in these buildings. Reducing the church's energy use will save money, decrease greenhouse gas emissions, help protect our environment and honour our relationship with God's creation. There are good opportunities to cut energy costs and reduce energy waste in the church buildings.

It is found that over 75% of the churches in Hong Kong are located inside commercial, residential and school buildings; there are also some stand-alone church buildings which have historic value to architectural conservation. The main energy conservation potential is related to the design, operation and management of the lighting and air conditioning systems. To achieve successful outcomes and results, both technology and people must be focused in building energy management and assessment.

When applying energy audit to church buildings, attention should be drawn to the architectural design and layouts, building operation and functions, heritage conservation and the liturgical spirit and norms. Most churches use the entirety of their facilities only a few days a week, so there is a need for flexible space to accommodate the various configurations and multiple uses to which church space is put. This can ensure the church will be better equipped to design or upgrade the facility to reach optimal energy efficiency. The results from the energy assessment can be exploited in retrofit design when energy efficiency improvements are considered in connection with a major renovation for the church buildings.

Major recommendations for energy management of church buildings are:

1. Each congregation shall assemble an energy management team.
2. Energy accounting and information systems shall be developed and promoted to the churches.
3. A high-level energy management and conservation policy shall be set up in the church body to express the commitment to energy efficiency.
4. A procurement policy shall be set up in churches to ensure only efficient equipment and products will be taken.
5. Energy audit forms and guidelines for church buildings shall be developed.
6. Energy performance and management shall be considered seriously in church renovation projects.

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St. Jude’s Church (聖猶達堂)
St. Stephen’s Church (聖斯德望堂)

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List of Abbreviations

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BEC	Building energy code
BEEO	Buildings Energy Efficiency Ordinance
BSE	Building services engineer
CFL	Compact fluorescent lamp
CIBSE	Chartered Institution of Building Services Engineers
CMCG	Catholic Messengers of Green Consciousness
CO_2	Carbon dioxide
CRES	Centre for Renewable Energy Sources
CRT	Cathode ray tube
CSD	Council for Sustainable Development
DCV	Demand-controlled ventilation
EAC	Energy audit code
ECF	Environment and Conservation Fund
EEO	Energy Efficiency Office
EMO	Energy management opportunity
EMSD	Electrical and Mechanical Services Department
EPD	Environmental Protection Department
EUI	energy utilisation index
FCG	Faith & the Common Good
HAESCO	Hong Kong Association of Energy Service Companies
HKSAR	Hong Kong Special Administrative Region
HKU	The University of Hong Kong
HVAC	Heating, ventilation and air-conditioning
LCD	Liquid crystal display
LED	Light emitting diode
M&V	Measurement and verification
MCGB	The Methodist Church of Great Britain
O&M	Operation and maintenance
PCM	phase change material
PDCA	Plan-Do-Check-Act
PEA	Preliminary energy-use analysis
PV	Photovoltaic
REA	Registered Energy Assessor
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
TFSC	Task Force for The Stewardship of Creation
UCA	Uniting Church in Australia
USEPA	U.S. Environmental Protection Agency
UV	Ultra violet
VOC	Volatile organic compounds
VRF	Variable refrigerant flow
VSD	Variable speed drive
VVVF	Variable voltage variable frequency

1. Introduction

Churches around the world are beginning to acknowledge their role, as people of faith, in helping to protect the environment and tackle the climate change issue (Climate Change Centre, 2006). In Genesis 2:15 we read "The God took the man and placed him in the garden to till it and keep it". Our planet is God's creation, the planet Earth is given to us as the source of life but, too, we have the responsibility to look after our environment (Bartlett, *et al.*, 2006). Applying good principles of creation stewardship to the operation and care of the church buildings can help the congregation obediently adhere to God's call to "tend and keep" the creation.

One way a church can start to move forward on this shared concern for the environment is through making their buildings more energy efficient (FCG, 2007). Making a church building energy efficient may not seem like a big deal, but wasted energy not only increases building operational costs, it also adds to the amount of greenhouse gases being released into our atmosphere (DeVries, 2002). As we are currently seeing, the resultant global warming can have huge effects on our lives and the lives of our loved ones. Thus, reducing the church's energy use will save money, decrease greenhouse gas emissions, help protect our environment and honour our relationship with God's creation (UCA, 2009).

1.1 Objectives

The main objective of this research study is to investigate the energy audit process and energy management opportunities for church buildings in Hong Kong. The aim is to develop practical information and guidelines for promoting energy conservation in these buildings which are not often noticed and given the enough attention to. It is hoped that the research findings will not only benefit the society of Hong Kong but can also provide useful information and hints to other cities in the world with similar situations.

Usually energy consumption was not a particularly important concern when a church building was first built or a congregation was founded. However, like many congregations, the church is often housed in a facility that has been expanded, renovated, and changed over time. With the growing concern on environmental issues, energy conservation and stewardship have become more and more important on the list of goals of a church (TFSC, 2010; USEPA, 2007).

There are good opportunities to cut energy costs and reduce energy waste in the church buildings (MCGB, 2010). In fact, churches and other faith based organisations can save much money in the annual energy costs. The savings can free up their resources to be used for other aspects of ministry such as outreach and community service. These savings are especially critical to churches struggling to faithfully serve their communities with limited financial resources.

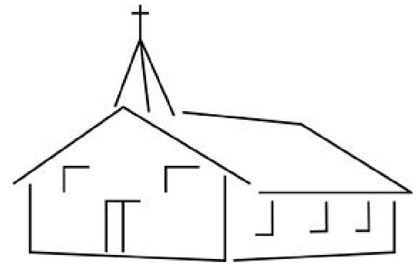
As energy use and energy savings will directly affect the amount of carbon emission reduction in the society, it is very important to foster and implement measures on demand-side management of energy and electricity consumption, in order to reduce Hong Kong's carbon intensity (CSD, 2011). The way that we use energy in buildings is crucial to achieving these savings. It is believed that the church buildings can set good examples to other organisations, influence the attitude of other people in the local community on combating climate change and motivate relevant sectors to grasp the opportunities in building energy efficiency. By promoting such actions, we can call upon our people to devote energy to studying and understanding the admittedly complex issues connected to the stewardship of the earth (Religious Buildings Initiative, 2009).

As the new Buildings Energy Efficiency Ordinance (BEEO) (Cap. 610) (www.beeo.emsd.gov.hk) has come into full operation in Hong Kong on 21 September 2012, it is hoped that this research can help promote building energy efficiency in different sectors of the society. Appendix I provides a summary of the BEEO and its requirements.

1.2 Organisation of This Report

This report is divided into six Chapters. The detailed information and resources are put in the Appendices at the end of the report.

Chapter 1 is the introduction to describe the background and objectives of the research study. Chapter 2 explains the major findings on typical church buildings in Hong Kong and their characteristics. Chapter 3 provides a systematic guidance on the energy audit process and Chapter 4 explains the common energy management opportunities for the church buildings. Chapter 5 discusses the major considerations for promoting energy conservation in church buildings and highlights the need for people's involvement. Chapter 6 gives the conclusions of this research study and provides major recommendations.



2. Church Buildings in Hong Kong

The church buildings were established by Christianity which has been in Hong Kong since 1841. In 2011, of about 843,000 Christians in Hong Kong, most of them are Anglican, Protestant and Roman Catholic (HKSAR Government, 2012). The Protestant, Orthodox and Roman Catholic churches maintain a spirit of fellowship with the Hong Kong Christian Council, the Orthodox Metropolitanate of Hong Kong and Southeast Asia (based in Hong Kong) and the Roman Catholic Diocese.

According to HKSAR Government (2012), the Protestant movement in Hong Kong began in 1841 and has a current registered membership of about 480,000 followers. The Protestant community, composed of more than 70 denominations with at least 1,400 congregations, is deeply involved in education, health care and social welfare. Protestant organisations operate three post-secondary institutions, 180 secondary schools, 199 primary schools, 260 kindergartens, 127 nurseries and more than 35 theological schools. Protestant organisations also run seven hospitals, 17 clinics and 107 multi-social centres that provide a wide range of social services.

The Roman Catholic Church in Hong Kong was established as a mission prefecture in 1841; became a vicariate apostolic in 1874; and a diocese in 1946. There are about 363,000 Catholics in Hong Kong served by 309 priests, 54 brothers and 489 sisters. There are 51 parishes, comprising 40 churches, 33 chapels and 26 halls for religious service. The diocese has its own administrative structure while maintaining close links with the Pope and other Catholic communities around the world. The diocese has 278 Catholic schools and kindergartens catering to about 192,000 pupils. Medical and social services are provided to at least six hospitals, 12 clinics, 42 social and family service centres, 19 hostels, 14 homes for the aged, 25 rehabilitation service centres and many self-help clubs and associations.

2.1 Church Building Categories

Since 1989, the survey studies on census statistics of churches (including churches, chapels and cathedrals) were carried out every five years in Hong Kong. The latest census results (year 2009) indicate that there are about 1,250 churches in Hong Kong (Wu and Lee, 2010). Figure 2.1 shows the number of churches in Hong Kong in 1994-2009. It can be seen that the number is increasing steadily and the trend is likely to maintain in the coming future (Wu and Lee, 2011). Table 2.1 gives the percentage of the types of buildings for church in Hong Kong. It is found that many churches in Hong Kong are located inside commercial, residential and school buildings; there are also some stand-alone church buildings which have historic value to architectural conservation (see also Section 2.3).

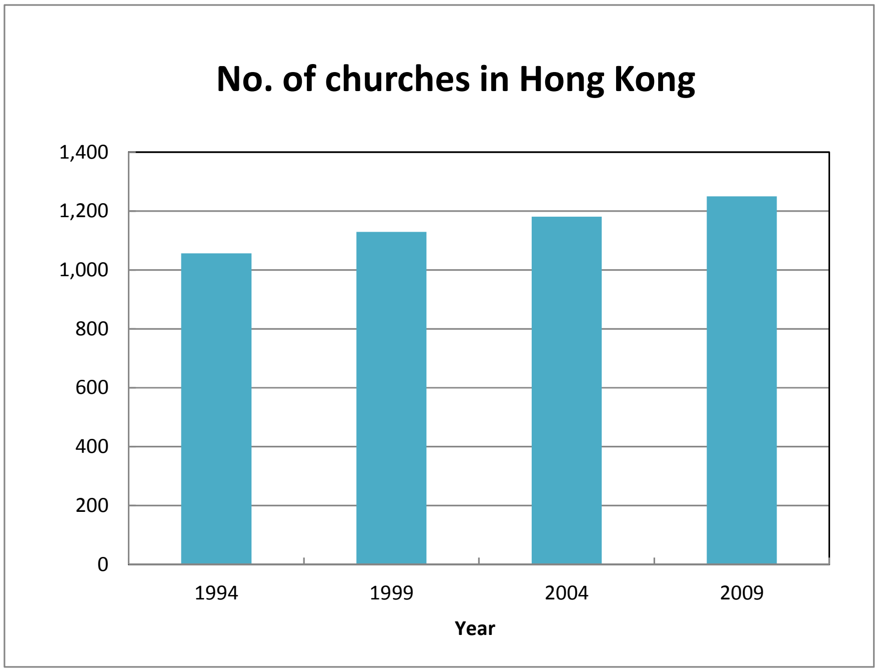


Figure 2.1 Number of churches in Hong Kong 1994-2009 (Wu and Lee, 2010)

Table 2.1 Percentage of the types of buildings for church in Hong Kong

Year:	1994	1999	2004	2009
Independent buildings	15.5	13.0	13.6	12.5
Inside commercial buildings	29.4	25.9	28.7	21.4
Inside residential buildings*	20.0	30.2	27.2	31.8
Inside school buildings	13.6	15.8	19.6	22.7
Inside social welfare buildings/centres	12.5	14.0	9.8	7.6
Inside industrial or office-industrial buildings	---	---	---	1.1
Others	9.1	1.1	1.2	2.9

(* including residential cum commercial buildings) Data source: (Wu and Lee, 2011)

Table 2.2 Percentage of the methods of setting the church buildings in Hong Kong

Year:	1994	1999	2004	2009
Self-owned	60.7	56.1	53.3	51.7
Use the venue of the congregation	27.6	21.2	21.6	24.2
Borrow the venue of the congregation	1.5	10.4	11.2	9.3
Rent the venue	10.2	12.4	13.9	14.8

Data source: (Wu and Lee, 2011)

As shown in Table 2.1, over half of the churches in Hong Kong are located in the upper-floor units in commercial and residential buildings. Because of their physical locations, these churches are sometimes dubbed upper-floor churches (Yeung, 2011). Unlike those that occupy stand-alone religious buildings or dwell in church-run schools and social service centres, these are often invisible in the landscapes of the city. Table 2.2 indicates the methods of setting the church buildings. Over 51% of them are self-owned, although the proportion is declining from 60.7% in the past 15 years. The percentage of rented venue is increasing from 10.2% in 1994 to 14.85 in

2009. Whether a church building is borrowed, owned or rented will have significant implications to the practice of building operation and energy management (see also Section 5.1).

2.2 Church Building Characteristics

Church buildings are important tools of gospel work and most often they are also serving as public facilities used by many different people for various purposes. Apart from offering religious instructions, many church bodies have established schools and provided health and welfare facilities to the community. Some church buildings are integrated with the schools or located next to them. Therefore, when considering the design and operation of church buildings, it is necessary to consider the nearby associated schools and facilities.

2.2.1 Traditional Church Buildings

A typical church building consists of assembly hall, offices and activity rooms. Usually the major functions of church building include assembling, worshipping christenings, gatherings, meetings, school activities, weddings and funerals. The key factors that determine how a church is designed and built include the nature of the local community and the location in city. Figure 2.2 shows a historical church building (St. John's Cathedral) in Hong Kong. It stands in the heart of the city's financial downtown district and is a much used and much loved building.

Figure 2.2 A historical church building in Hong Kong (Source: www.flickr.com/photos/oliwilken/)

Traditional church buildings are often built facing east, in the shape of a cross (a long central rectangle, with side rectangles, and a rectangle in front for the altar space or sanctuary). They usually have a dome or other large vaulted space in the interior to represent or draw attention to the heavens. The designs of synagogues and churches are very similar; they should express heavenly values with earthly materials (Wilkinson, 2002). Figure 2.3 shows a typical layout of a cathedral church. There are six major components in the internal design and layout of the church: (a) altar, (b) ambo (now called Lectern), (c) seat of the priest, (d) laity seating area, (e) Baptismal font, (f) other facilities and decorations (Braun, 1997).

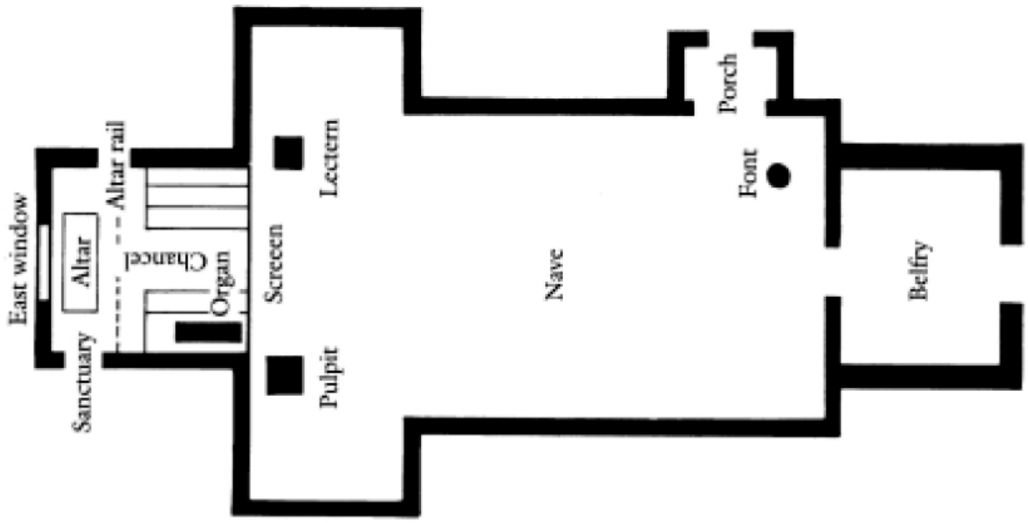


Figure 2.3 Typical layout of a cathedral church (Source: Instant Art for Teaching Christianity)

There is no uniform mode of furnishing a church. However, within latitude of individual initiatives, the liturgical spirit and norms, as defined by Vatican II, need to be adhered to (Hong Kong Diocesan Liturgy Commission, 1991). Thus, in fitting out churches, the priority is for vigorous simplicity, in order that the main emphases of liturgy are given their rightful place, without distracting the congregation's attention during worship. Furnishing and decoration of Catholic church interiors will need to follow the guidance and advice by a Taskforce for Liturgical Architecture and Art of the Hong Kong Diocesan Liturgy Commission (香港教區禮儀委員會 禮儀建築藝術小組) (http://www.catholic-dlc.org.hk/). There is a need to balance the requirements of liturgical spirit, arts, religious culture, architectural and engineering aspects (Law, 2004; Law, 2001).

2.2.2 Recent Church Buildings

More modern church buildings have a variety of architectural styles and layouts with contemporary design and building systems (Roberts and Daly, 2004). Many buildings that were designed for other purposes have now been converted for church use; and, similarly, many original church buildings have been put to other uses. Nevertheless, the church interior should inspire feelings of wonder and awe; there should be a sense of spaciousness and grandeur (even in a small church) which lifts the heart and mind to heaven. Since a church is for people to gather for divine worship, the seating should be comfortable. Everyone should be able to see the altar and the pulpit. There should be a good sound system and adequate amenities like air conditioning, toilets and cry rooms and bride rooms.

In Hong Kong in recent years more new churches were built and old ones renovated. With ever scarcer land supply and rising construction costs, the new churches of today have taken on a completely new look, both inside and out, with very distinctive architectural expressions (Yeung, 1991) and local characters (Law, 2004).

Recent churches, particularly those in the densely populated urban districts, are generally designed as multi-functional complexes to maximise land use: housing church, assembly hall, catechetical and activity rooms, offices and other facilities, such as kindergarten and car park, all under one roof. These new, composite building forms have also provided building designers with the opportunity for creative interpretation, making their appearances more striking and pregnant with symbolism, as if to convey a clearer message that they are dwellings of the Lord.

Yeung (1991) pointed out that traditionally most churches adopted a rectangular plan, which increased the separation between celebrant and congregation, thus weakening the sense of participation and inadvertently leading to prayer in private and passiveness of attendance during the celebration of liturgy. In new and refurbished churches, innovations leading to unconventional layouts, such as a fan-shaped or semicircular interior, have resulted in reducing the distance between celebrant and congregation, fostering a sense of concentricity and community. Worshippers are thus encouraged to participate with one heart and one mind, in turning to the Word and the Christ on the altar.

2.2.3 Patterns of Energy Use

Most churches have a large worship space and/or hall which requires significant energy to cool and/or light up (UCA, 2009). For spiritual and personal reasons, the sanctuary space is very important to congregational members (USEPA, 2007). With this in mind, a sanctuary space is typically designed to provide a tranquil environment for worshipers and their families. And, an important part of creating this environment of “comfort and aesthetics” is through the optimal use of energy. Churches usually have multiple users so any behaviour change strategies have the additional challenge of requiring to be targeted to various groups.

Congregational buildings have unique needs because their energy-use patterns are often very different from other buildings. Residential and/or commercial buildings require relatively constant energy but congregation energy use tends to peak on weekends and lessen during the rest of the week with occasional spikes for special meetings and other functions. A large portion of a congregation’s energy costs goes toward keeping the facility comfortable during the days (such as Sundays and Saturdays) when the facility is being used. This includes lighting and air conditioning of the halls and activity rooms.

The main problem is that most churches are massive buildings, often of historic value, and used for only a few hours each week. This makes the economics of environmental control and building services a different problem from that of most other buildings. Traditionally some churches have been very energy inefficient, this is in part due to their age and design but despite this much can be done to make churches more energy efficient places of worship through simple procedural and behavioural changes (see Chapter 4 for details).

2.3 Historical Church Buildings

Conservation of historic buildings is significant to a society for protecting its cultural resources and preserving important heritage (Hui and Leung, 2004). In recent years, the people in Hong Kong have been increasingly aware of the issue of the demolition and redevelopment of historic buildings. Heritage conservation has become a major concern of the public. As present, there are 101 declared monuments and over 1,000 graded historic monuments in Hong Kong. Historic buildings in Hong Kong are classified into three gradings; the buildings are graded on the basis of historical interest, architectural merit, group value, social value and local interest, authenticity and rarity.

Church buildings are invaluable historical resources, with some standing as the best examples of our architectural achievements and cultural heritage. At present, one church building in Hong Kong is a declared monument (St. John's Cathedral, Garden Road, Central) and 35 church buildings are graded historic monuments (Grade 1 to 3). Appendix II gives a list of those graded historical church buildings in Hong Kong. In fact, there are many other church buildings in Hong Kong which have significant heritage value and will require the preservation.

When considering the energy efficiency measures for historical church buildings, it is important to understand the heritage values and observe the conservation principles (English Heritage, 2008). Otherwise, the values of those buildings tend to be quickly obscured or lost. Balanced and justifiable decisions about the energy saving methods must be developed to eliminate or minimise adverse impacts on significant places in the old church buildings which is a cultural resource for learning and enjoyment. The theological and historical considerations of the church buildings must be taken into account (White, 1964).

Usually, the church renovation work will perform the essential maintenance only and restore only the essential parts (Kung Kao Pao, 2006). Unnecessary renovation work would be reduced to the minimum. Only the parts that could be restored to its original look would be renovated. In fact, a good renovation work not only helps to preserve the historical value of buildings, it can also enhance the appearance and energy efficiency of the buildings.

2.4 Case Studies

In order to develop a better understanding of the church buildings in Hong Kong and their energy use characteristics, a few examples of churches have been studied by conducting site visits and energy assessments in 2011-2012.

2.4.1 Church Buildings Studied

In late 2011 to early 2012, three historical church buildings have been identified and studied. Table 2.3 gives a summary of these church buildings. Because of the lack of information on the historical electricity use, estimation has been made to determine the annual electricity consumption based on incomplete data. Through an energy audit process, the building characteristics and energy consumption profiles of these church buildings were examined; the possible energy saving measures were identified and analysed (Chan, 2012). It is found that although some guidelines on commercial building energy audits are available in the industry, they are not completely suitable for church buildings. The main energy conservation potential of these buildings is related to the design, operation and management of the lighting and air conditioning systems. Useful information and experience have been obtained for the evaluation of the church building characteristics and energy management opportunities (see Chapters 4 and 5 for elaboration).

Table 2.3 Historical church buildings studied in late 2011 to early 2012

Name	Chinese Rhenish Church	Kau Yan Church	St. Anthony Church
Location	Bonham Road	High Street	Pokfulam Road
Year Built	1941	1932	1953
Partner school	Rhenish Mission School	Kau Yan School	St. Anthony's School
Total floor area	990 m^2	1,053 m^2	585 m^2 (hall only)
Historic grade	Proposed Grade 3	Grade 1	Grade 2
Annual electricity consumption*	112,050 kWh	192,700 kWh	142,550 kWh

* Estimated based on incomplete data.

During the summer of 2012, further investigations have been carried out on three other church buildings. The aim is to apply the energy assessment concepts developed from the previous cases and to collect more information for different types of church buildings in Hong Kong. Table 2.4 shows a summary of the church buildings studied in the summer of 2012. In terms of building age and conditions, the buildings listed on Table 2.4 are more recent than the previous cases on Table 2.3. One of them has been renovated in recent years and the other two are considering a major renovation for the coming future. The annual electricity consumption is estimated based on the average of the available historical data on electricity use.

Table 2.4 Church buildings studied in the summer of 2012

Name	Our Lady of the Rosary Church	St. Jude's Church	St. Stephen's Church
Location	Kennedy Town	North Point	Kwai Chung
Year Built	1960	1952	1980
Partner school	St. Charles School	St. Jude's Kindergarten	St Stephen's Church Kindergarten
Total floor area	1,004 m^2	3,761 m^2	2,266 m^2
Annual electricity consumption*	49,017 kWh	160,043 kWh	137,230 kWh

* Estimated based on the average of the available historical data.

2.4.2 Energy Consumption Profiles

Like most other buildings in Hong Kong, electricity is the major form of energy use in the church buildings. Efforts have been made to collect and evaluate the electricity consumption of the church buildings. Figures 2.4 to 2.6 show the monthly electricity consumption for three church buildings studied. The period of the data varies from 1 year to 3.5 years. Unfortunately, further breakdown of the consumption data is not feasible due to lack of information.

In practice, it is not easy to collect and analyse the historical energy consumption data for the church buildings because the electricity bill records are sometimes not well documented and maintained. Also, some church buildings are linked to the school facilities and their electricity bills might mix together for some areas. Without proper sub-metering and management information, it is not possible to obtain a reliable and consistent set of energy consumption data for the church buildings. In addition, it is not possible to establish the energy utilisation index (EUI) and breakdown of the energy use components for comparing the building energy performance.

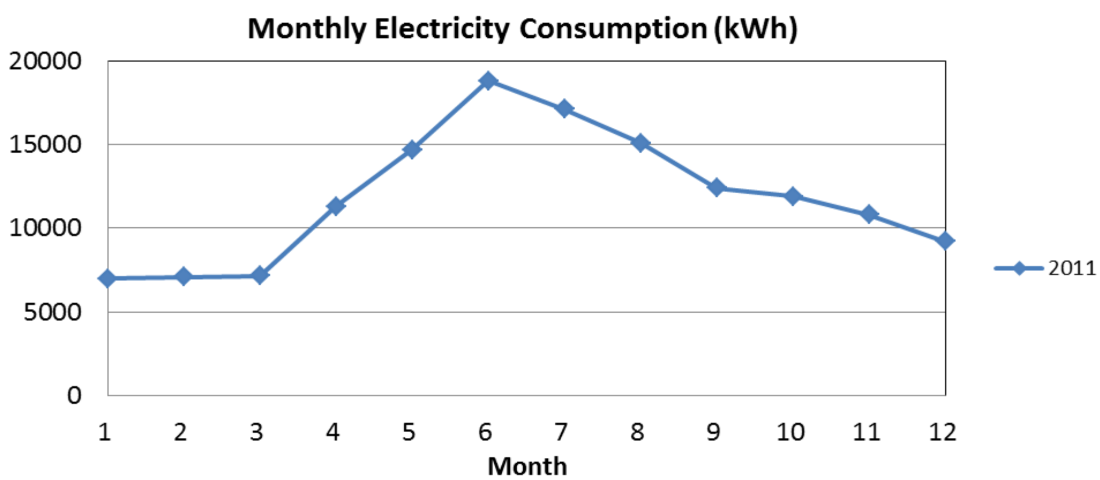


Figure 2.4 Monthly electricity consumption of church building A

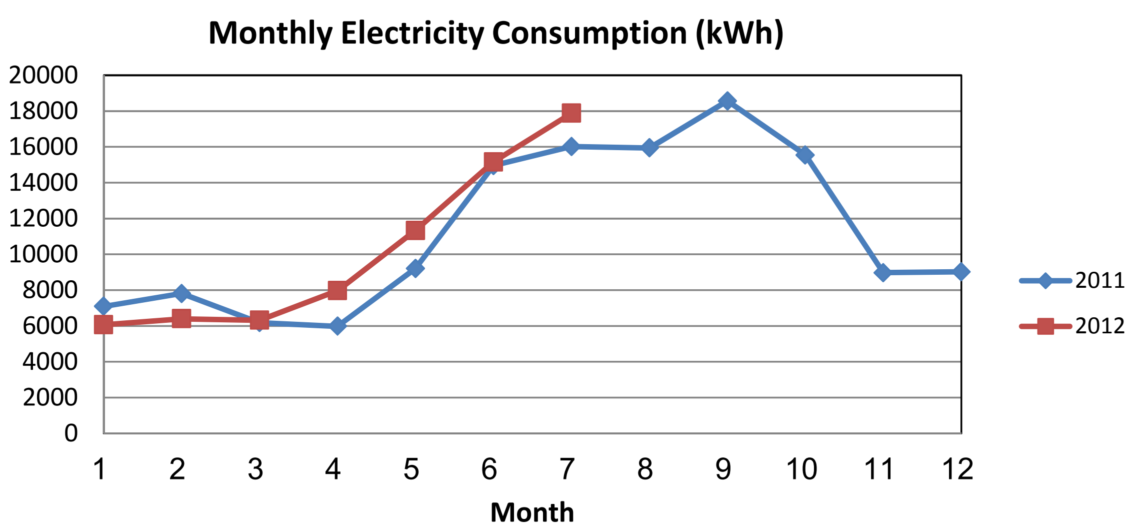


Figure 2.5 Monthly electricity consumption of church building B

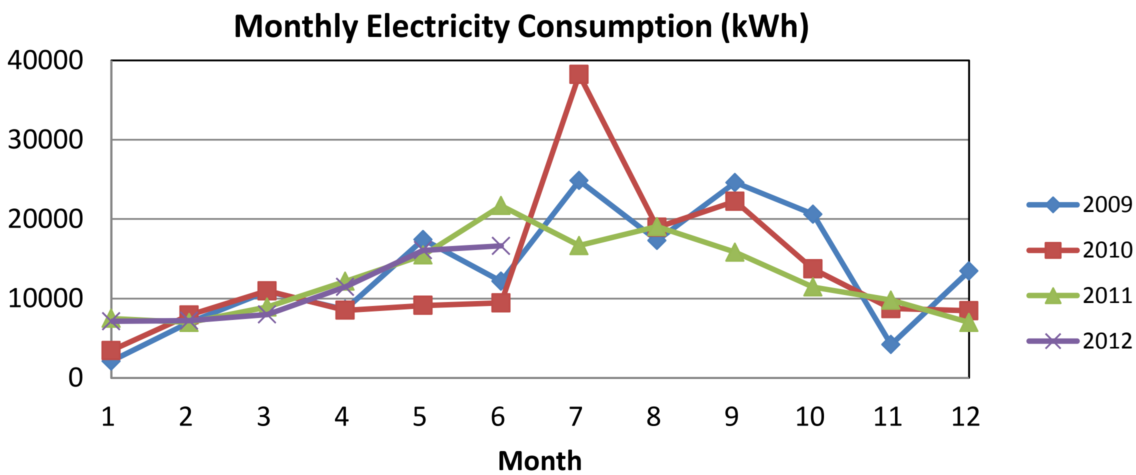


Figure 2.6 Monthly electricity consumption of church building C

Based on the electricity consumption profiles on Figures 2.4 to 2.6, it can be observed that the energy use during the summer months (May to October) is much higher than that during the other months (January to April, November to December). This indicates that weather condition has a significant influence on the energy use because most likely air conditioning is required and often applied in the summer months. The actual energy use is also affected by other factors such as operation schedule and user behaviour of the church building. Usually, the weekend worship gatherings are regular, but special functions will vary (no records to trace).

It is important to develop a systematic approach to build up the information for decision making of the building energy management. An energy accounting and information system will be useful for the church buildings to keep and review the related building energy data.

3. Energy Audit Process

Energy audit is an important tool to identify and evaluate energy saving opportunities (CIBSE, 1991; CIBSE, 2012; CRES, 2000; Krarti, 2011; Thumann and Younger, 2007). It can be applied to church buildings to improve their operations and design (TFSC, 2010; UCA, 2009). By definition, an energy audit is "an examination of an energy consuming equipment/system to ensure that energy is being used efficiently" (EMSD, 2007). It involves "the systematic review of the energy consuming equipment/systems in a building to identify energy management opportunities (EMO), which provides useful information for the building owner to decide on and implement the energy saving measures for environmental consideration and economic benefits" (EMSD, 2012b). Usually the building manager or energy assessor will examine the energy account of the equipment/system, check the way energy is used in its various components, check for areas of inefficiency or that less energy can be used and identify the means for improvement.

The term "energy audit" is an established term widely used and understood in the industry. However, the word "audit" is perceived by many people as carrying the negative connotations because it is often associated with an involuntary investigation of finances, where the intended goal is to uncover mistakes and assess monetary penalty (ASHRAE, 2011). In order to gain better acceptance by the building managers and operators, such negative connotations are best avoided. Therefore, nowadays, the term "energy assessment" is preferable to "energy audit". In this report, both terms are used interchangeably. It is important to avoid the unpleasant feeling and ensure that the building management should be provided with the right perception of the benefits of the energy audit.

3.1 Basic Principles

An energy audit analyses the present energy use of the building and points out profitable saving measures. It is a systematic procedure with the aim to evaluate the existing energy consumption, identify the saving measures and report the findings. When applied to church buildings, it is a systematic way of assessing what energy resources are currently being used by the church and evaluating ways to reduce energy consumption (TFSC, 2010). This evaluation considers any initial costs for energy efficient upgrades as well as the amount of time it will take to recover this financial investment through reduced energy costs. Energy audit is a crucial first step in establishing an energy management programme and can provide the information needed to make decisions on which are the most cost effective energy saving measures (CIBSE, 2012). Usually it should be undertaken regularly, typically every three to five years.

3.1.1 Energy Audit Guidelines

In Hong Kong, the Energy Efficiency Office (EEO) of the Electrical and Mechanical Services Department (EMSD) has developed a set of guidelines on energy audit for commercial buildings (EMSD, 2007). The guidelines provide building end-users, building owners, building management, operation and maintenance personnel comprehensive information on how to conduct energy audits, propose energy management opportunities and write up audit reports as well as cover a wide range of issues including the audit procedures, the report format and the required audit skills. Together with the Building Energy Code (BEC) and Energy Audit Code (EAC) in Hong Kong (EMSD, 2012a & b), they form a useful toolkit for promoting building energy efficiency. Figure 3.1 shows a flow chart on procedure of energy audit as recommended in the guidelines. It indicates the overall concept of the energy audit process which is divided into three stages: (a) pre-audit stage, (b) energy audit stage and (c) post-audit stage.

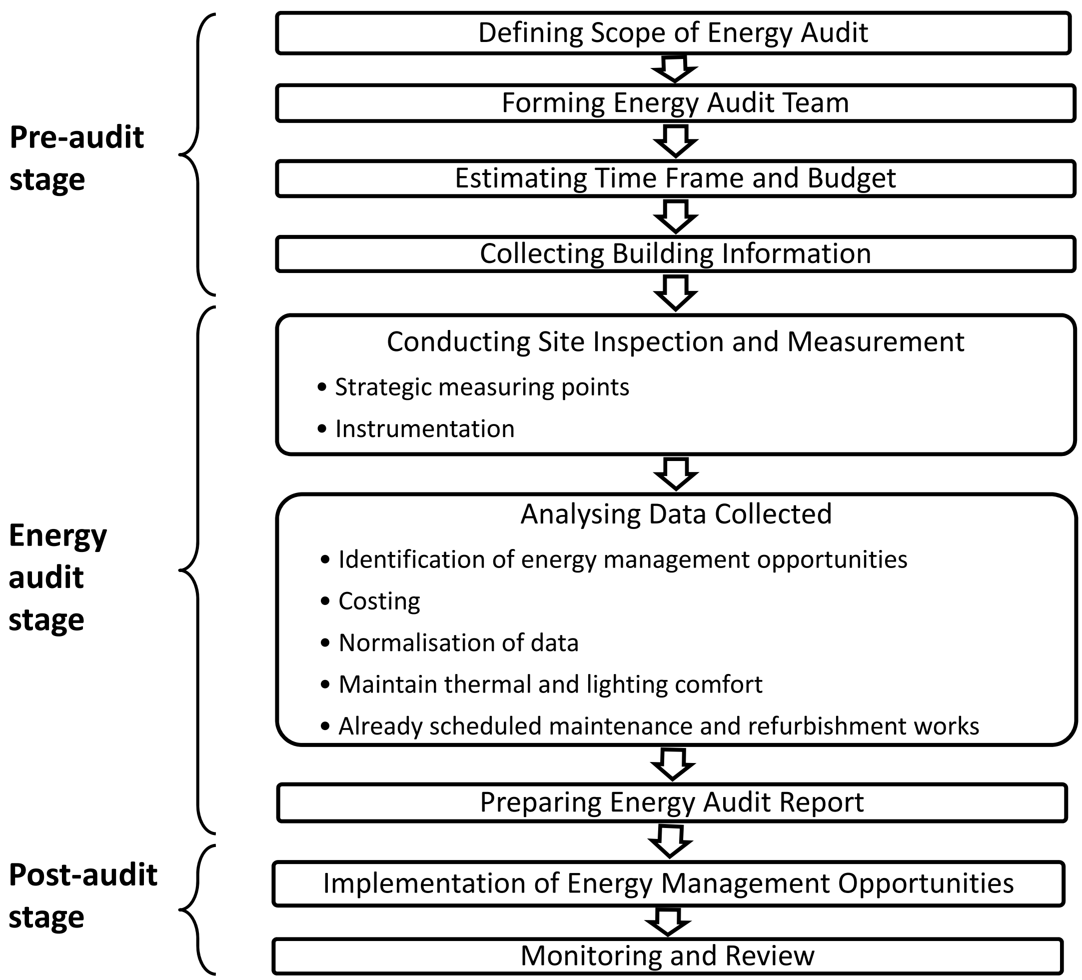


Figure 3.1 Procedure of energy audit [adapted from EMSD (2007)]

In this research, the EMSD guidelines were used as a reference for developing an effective approach to energy assessment and management of the church buildings.

When applied to church buildings, particular attentions have been paid to the architectural design and layouts, building operation and functions, heritage conservation and the liturgical spirit and norms. For example, the energy audit forms and checklists have been modified to suit the needs of church buildings.

In addition, useful references from other countries on energy audit and management of buildings (ASHRAE, 2011; CIBSE, 2012; CRES, 2000; Doty, 2008; Fetters, 1998; Krarti, 2011; SMACNA, 1997; Thumann and Younger, 2007; Wendes, 1995) have been studied so as to establish best practices for the energy auditors/assessors and provide updated information on energy auditing methods. For example, Table 3.1 shows the key elements of the energy audit process as described in ASHRAE (2011). This can provide guidance on best practices for conducting building energy assessments and implementing the energy saving measures.

Table 3.1 Key elements of the energy audit process (ASHRAE, 2011)

Building an Audit/Implementation Team	▪ Assembling the right participants and establishing clear responsibilities
Preliminary Energy Use Analysis	▪ Analysis of two or more years of utility consumption cost
Site Visit Procedures	▪ Activities to prepare for the on-site audit
Measurement	▪ Site visit and audit of building to collect data to quantify operating parameters and performance
Analysis	▪ Description and analsysis of the energy-using systems of the building ▪ Can include a whole building energy model
Energy Efficiency Measure Types	▪ Classify the recommended energy efficient measures and bundle together synergistic measures
Economic Evaluation	▪ Evaluate the capital costs and life cycle cost of efficiency measures and bundle of efficiency measures
Developing an Audit Report	▪ Provide complete information needed by an owner/operator to decide whether to implement recommended measures
Presentation	▪ meet with the owner/operator to review the report, explain results, and plan the next step
Implementing Measures	▪ Implement the chosen efficiency measures ▪ includes Measurement & Verification and continuous commissioning

3.1.2 Energy Audit Team and Levels of Effort

In principle, the energy audit should be carried out by a competent person or team with sufficient technical knowledge on building services systems (such as lighting and air conditioning systems) and energy management techniques. EMSD has maintained a list of Registered Energy Assessors (REA) who are relevant professionals in the industry (see www.beeo.emsd.gov.hk for details). The number of auditors and time required for an audit depends on the audit scope and objectives.

The level and extent of an energy audit should be determined by the likely potential for savings and the necessary investment in time and resources (CIBSE, 2012). For a simple on-site walk-through survey and reporting, in-house personnel or even the church's youth group can perform them. But for a more detailed building survey and energy analysis, energy audit consultants should be employed. When an outside specialist is commissioned, a clear understanding must be established on both sides as to the objectives.

About the levels of effort of energy audit, ASHRAE (2011) has suggested the following categories.

- Preliminary Energy-Use Analysis (PEA)
- Level 1 – Walk-Through Analysis
- Level 2 – Energy Survey and Analysis
- Level 3 – Detailed Analysis of Capital-Intensive Modifications
- Targeted Audits (of a specific system or end use, such as the chiller plant)

Regardless of the level of audit being pursued, the key elements in the systematic approach remain the same (see Table 3.1). A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

During the audit process, the auditor will need assistance and cooperation from the end-users, building manager/engineer, operation and maintenance (O&M) personnel, etc. because they are more familiar with the building and its operation characteristics. More often than not, they can provide valuable information and good suggestions to the energy audit team. By actively involving the end-users and building staff, the process can ensure that their concerns are heard, that their observations about the building add value, and that those who will be asked to maintain the building are familiar with recommended equipment and controls (ASHRAE, 2011).

If the church is located inside commercial, residential and school buildings, it is necessary to consider if the energy audit could be applied to the whole building complex. One advantage of doing this is that the efforts and resources needed for the energy assessment can be shared and reduced. For many church bodies, unless they have voluntary audit team members, it is essential to control the manpower budget for the energy audit process.

3.1.3 Energy Management Opportunities

The means to achieve energy efficiency and conservation is called energy management opportunity (EMO). According to the cost and the complexity for implementation, EMOs are classified into three categories as shown in Table 3.2. Usually the no cost energy saving measures (EMO category I) are most attractive and receive priority. Appendix III gives the examples of no or low cost energy saving measures for church buildings in Hong Kong.

Table 3.2 Three categories of energy management opportunities (EMSD, 2012b)

Category I (no cost)	involving housekeeping measures which are improvements with practically no cost investment and no disruption to building operation
Category II (low cost)	involving changes in operation measures with relatively low cost investment
Category III (high cost)	involving relatively higher capital cost investment to attain efficient use of energy

The energy saving measures under EMO category II will require small capital investment for the engineering work and they usually can offer a simple payback period of less than 3 years. The projects involving EMO category II or III have to be analysed, engineered and budgeted for implementation in a phased manner. Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns, and may require careful scrutiny before funds can be committed. These projects are generally complex and may require long lead times before they can be implemented. For example, the upgrading and replacement of major air conditioning plant will require higher capital investment and can provide high return and better quality of service. Further information about the EMOs for church buildings will be discussed in Chapter 5.

As mentioned before in Section 2.2, energy use patterns associated with churches, synagogues, and other houses of worship are usually different from those of other buildings. Demand for energy may be periodic rather than constant during the week and peak on weekends, making energy management a challenge. During the energy audit process, it is necessary to study the situation carefully on weekends and collect information about the major church events and functions. If a clear understanding of the church building operation and management can be achieved, it will enable an effective energy conservation strategy to be designed and implemented.

3.2 Walk-through Energy Audits

A walk-through audit is the simplest type of energy audit and is the most basic requirement of the energy audit process (EMSD, 2007). It may deploy minimum resource to simply check for EMOs that are readily identifiable and to implement them to achieve savings immediately. Prior to the walk-through audit, the energy assessor may need to know the building and the way it is used from a preliminary survey or preliminary energy-use analysis (PEA). The information can be obtained from:

- Architectural drawings
- Air-conditioning technical drawings
- Electrical lighting and power technical drawings
- Utility bills and operation logs for the year preceding the audit
- Air-conditioning manuals and system data
- Building and plant operation schedules

The audit should be conducted by walking through the building and concentrating on the major energy consuming equipment/systems such as chillers, large air handling units, or common items usually with EMOs easily identifiable such as over-cooled spaces and inefficient lamps being used. Reference to record of equipment ratings, technical catalogue, O&M manuals that are readily available will be very helpful to quickly determine where equipment/systems are operating efficiently. Calculations, usually simple in nature, should be done to quantify the saving achievable from implementation of the identified EMOs. Appendix IV gives suggestions of a simple energy audit for church buildings.

Walk-through energy audits assess site energy consumption and relevant costs on the basis of energy bills-invoices and a short on-site autopsy (CRES, 2000). Housekeeping or/and minimum capital investment energy saving options of direct economic return are determined and a further list of other energy saving opportunities involving often considerable capital are proposed on a cost benefit basis. The audit should be carried out in one day by either one auditor or one audit team, depending on the size and the complexity of the building and the scope of the audit. If the audit team wants to check more areas, more auditor-hours are required. Usually, simple instruments such as thermometer tube, multi-meters and lux meter will serve the purpose.

3.3 Detailed-diagnostic Energy Audits

If the building management is highly committed to energy conservation and have allowed for adequate staffing and funding, a detailed audit should be adopted (EMSD, 2007). The audit team should check practically the majority or all equipment/systems, identify as many EMOs as possible, classify them into different EMO categories, further study if more complex items are involved, formulate a plan for implementation and finally present it to the building management. This audit goes much beyond the Walk-through Audit. The auditor has to exercise more detailed planning. The auditor-hours could be about 5 to 10 times more, depending on the complexity of the equipment/systems involved and size of the building. Normally, a comprehensive audit can take from several weeks to several months to complete.

Detailed-diagnostic energy audits request a more detailed recording and analysis of energy and other site data (CRES, 2000). The energy consumption is disaggregated in different end-uses (e.g. cooling, lighting, different processes, etc.) and the different factors that affect that end-use are presented and analysed (e.g. climatic conditions). All the cost and benefits for the EMOs that meet the criteria and requirements of the end-energy site administration are determined. A list for potential capital-intensive energy investments requiring more detailed data acquisition and processing is also provided together with an estimation of the associated costs and benefits.

The economic viability is often the key parameter for the management acceptance (CIBSE, 2012). The economic analysis can be conducted by using a variety of methods, such as pay back method, internal rate of return method, net present value method etc. For low investment short duration measures, which have attractive economic viability, simplest of the methods, payback is usually sufficient.

3.4 The Reporting of An Energy Audit

The reporting of an energy audit has two basic elements: the written energy audit report and a presentation on the main results. An oral presentation may have a significant effect on the implementation of the proposed energy saving measures. Even together with the simplest energy audit model there should be some kind of oral presentation of the results for informing the client and stake-holders as well as discussing with them the implementation strategy.

The reporting of the energy audit procedure can be done in principle at three different levels as shown in Table 3.3 (CRES, 2000). The three options are closely connected to the thoroughness of the audit work as well as to the programme level properties of monitoring and quality control. For church buildings which are usually not as complicated as commercial buildings, the ultra light or simple reporting would be good enough in most cases.

Table 3.3 Three different levels for reporting of an energy audit

Ultra Light Reporting	• Suitable for very small or simple buildings • It is very brief, focused and usually also very technical. It may include simple graphs and tables and is suitable for the scanning energy audit models • It concentrates strictly on the suggested energy saving measures • It might include a combination of: a summary, a check-list and a statement
Simple Reporting	• Suitable for small tertiary buildings where the total auditing budget is very limited • Concentrates on the detected energy saving measures • Includes descriptions of the proposed energy saving measures (savings and costs) • Shows the present consumption figures • Introduces the site very briefly
Detailed Reporting	• Suitable for all types of buildings but will require more efforts and resources • Includes a comprehensive description of the site (systems, operation, production) • Presents a breakdown of the total energy consumption (e.g. Sankey diagrams) • Introduces all profitable energy saving measures in detail, including some comments on implementation, saving calculations, cost estimates • Ranks the saving measures according to e.g. simple payback time • May show a comparison of the energy consumption data with statistical values, benchmarking indexes, etc.

The energy audit report should outline the objectives and scope of audit, description of characteristics and operational conditions of equipment/systems audited, findings in the audit, EMOs identified, corresponding savings and implementing costs, recommendations on EMO implementation and programme and any other follow-up actions (EMSD, 2007). Figure 3.2 shows a typical structure of an energy audit report.

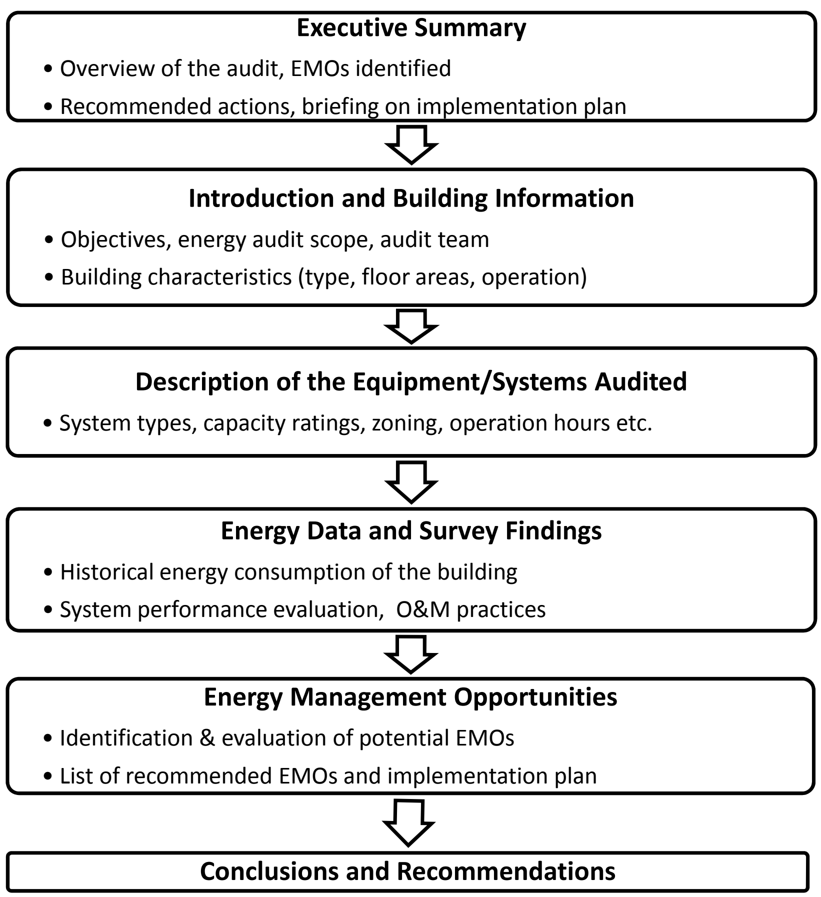


Figure 3.2 Typical structure of an energy audit report

4. Energy Management Opportunities

Energy waste occurs when the following three simple factors are not properly and regularly considered in church buildings (MCGB, 2010). Tackling the energy waste requires us to examine and evaluate the potential EMOs systemically and critically.

- Inefficient operation
- Inefficient equipment
- Building energy inefficiency

As observed from research findings of the case studies (see Section 2.4), two typical issues affecting the energy waste are:

- Lack of knowledge about what can and cannot be turned off
- Lack of dedicated person to ensure systems are regularly checked

In order to overcome the barriers and improve the energy management, it is very important to enhance organisational commitment, promote good housekeeping and modify/change occupant behaviour.

The major building systems and their related EMOs have been identified and discussed in this Chapter. Further information and guidance on EMOs can be found in EMSD (2007, Appendix J), USEPA (2007) and CIBSE (2012). Other useful resources and website information contained in Appendix V might also be helpful. For example, the following websites developed by EMSD can provide useful and practical information on energy management of buildings.

- HK Sustainable Technology Net, http://sustech.emsd.gov.hk
- HK EE Net, http://ee.emsd.gov.hk
- HK RE Net, http://re.emsd.gov.hk
- HK Green Building Technology Net, http://gbtech.emsd.gov.hk

4.1 Lighting Systems

Lighting retrofit of buildings has good potential to achieve energy-saving and functional benefits (Benya and Leban, 2011). Common ideas include changing out incandescent and fluorescent lighting for compact fluorescent lamps (CFLs) or light emitting diode (LED) sources. The current lighting technologies and economics are mature and competitive enough for CFL and LED light fittings to be widely adopted in buildings (read "http://eartheasy.com/live_energyeff_lighting.htm" for a guidance on the selection of CFL and LED lighting). It is necessary for the churches to study and identify the opportunities to upgrade the lighting systems and related equipment. This not only can improve energy efficiency but also can enhance control flexibility and lighting quality. Usually the cost effectiveness of the lighting upgrade will be higher for those systems operating continuously for long hours, such as replacing the conventional incandescent or fluorescent exit signs with the new LED exit signs can increase the energy efficiency by 3 to 8 times.

4.1.1 Daylighting Design for Church Buildings

As described in Section 2.2, the assembly halls of church buildings usually have high headroom to give a sense of spaciousness and grandeur. They also have stained glass windows and other fenestrations to promote natural daylight. Figure 4.1 shows examples of the use of daylighting in two church assembly halls in Hong Kong. If the site environment of the building permits, natural daylight can be fully utilised for the interior and the energy consumption of electric lights can be reduced. Figure 4.2 shows an example of using light pipe for admitting natural daylight into buildings.

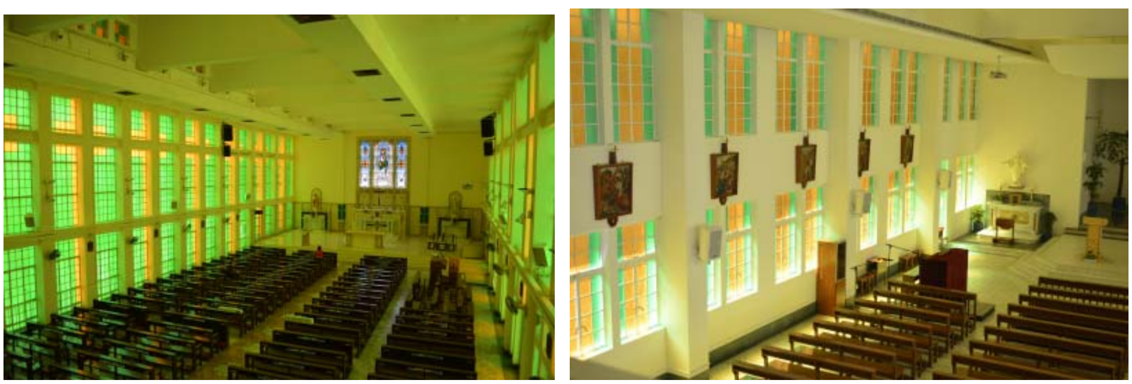


Figure 4.1 Use of daylighting in two church assembly halls in Hong Kong

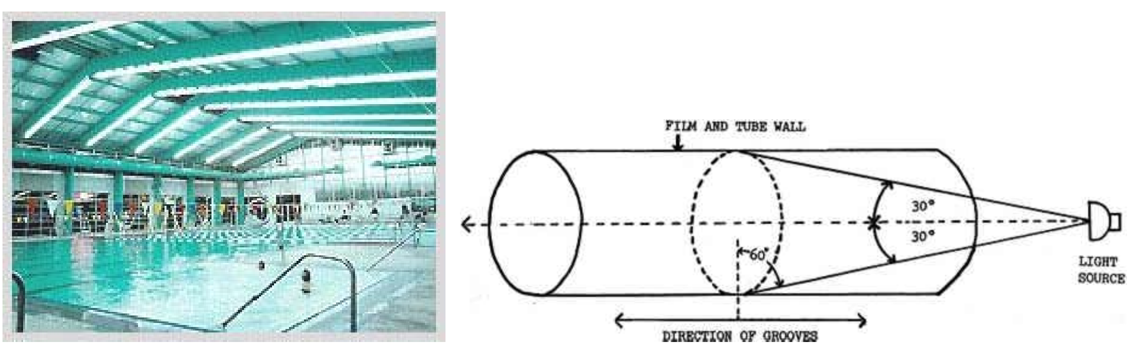


Figure 4.2 Light pipe for admitting natural daylight into buildings (Source: 3M.com)

4.1.2 Sanctuary Lighting

Lighting plays a critical role in defining the look and feel associated with the tranquil environments of a sanctuary (USEPA, 2007). It is not only necessary for viewing and reading but it also provides architectural accents and a feeling of warmth throughout the space. For church buildings, the sanctuary lamp is lit to show that bread from communion or mass is in the nearby tabernacle (it is always lit night and day except for Good Friday and Holy Saturday); lamps are also used for illuminating statues and images. Therefore, the energy saving potential is large. Figures 4.3 and 4.4 show the examples of sanctuary lighting in the churches in Hong Kong.

Figure 4.3 Sanctuary lighting for a church building in Hong Kong (for a crucifix, a cross with the figure of Jesus on it, on the wall behind the altar)

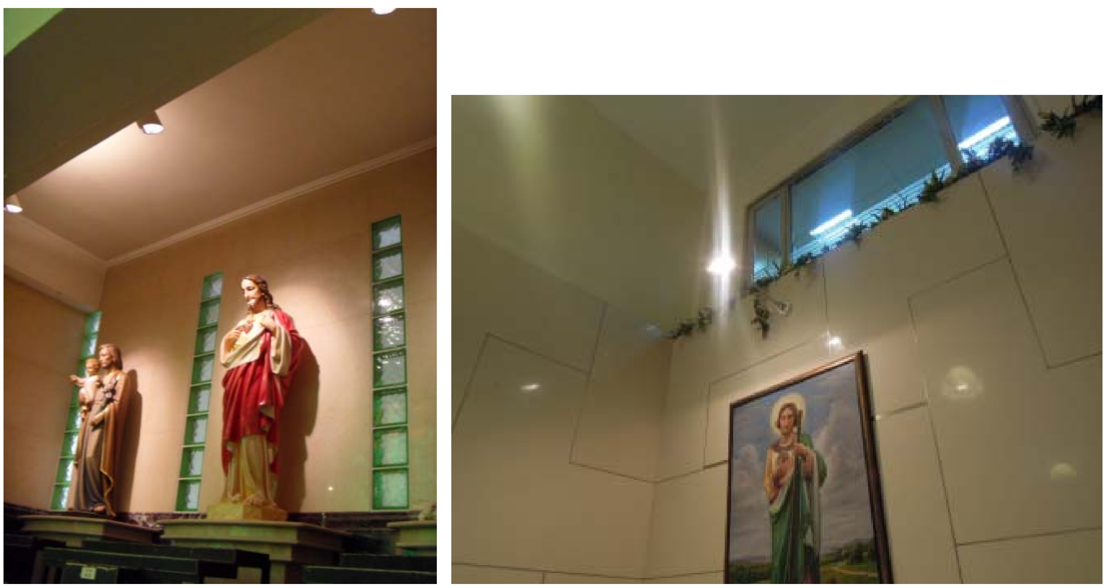


Figure 4.4 Sanctuary lighting for statues and images

CFL and LED light fittings can be used for the recessed cans, pendant fixtures, and accent and spot lighting applications. They can meet both the energy-efficient and aesthetic needs of the congregation. With effective controls, lighting can be used more efficiently. Many sanctuary spaces have limited options in the use of their lighting system. Better controls will allow more flexibility, create a more comfortable environment for the occupants, and reduce energy waste by allowing the use of only those lights that are needed.

4.1.3 Lighting Controls

Controls are a key part of any lighting system (USEPA, 2007). It is essential to specify controls that maximize the flexibility of the system while eliminating light usage, often automatically. Common lighting controls include:

(a) Bi-level Switching: Control of a lighting system in groups of fixtures or lamps, for example bi-level switching allows people to turn-half of the lights in a room off when full illumination is not required. Bi-level switching is commonly used in offices, conference rooms, and classrooms.

(b) Dimmers: Dimming lighting systems allow people to control the amount of light and save energy. Dimmers are available for fluorescent and incandescent systems. Daylight dimmers are special sensors that automatically dim room lights based on the amount of free and natural daylight available.

(c) Occupancy Sensors: These sensors detect the motion of occupants, turning off lights in unoccupied areas and turning them back on when movement is detected. Occupancy sensors are commonly used in restrooms, classrooms, corridors and staircases.

(d) Daylight Sensors (Photocells): A common inefficiency of exterior lighting systems is a tendency to "dayburn." This is when lights are on during the day, wasting energy and money. This problem can be prevented by installing light-sensitive controls that turn the lights on and off automatically based on daylight, thus producing convenient energy savings. Timers can be used, but do not react to changing daylight conditions.

4.1.4 Scheduling and Zoning

Most congregations use the entirety of their facilities only a few days a week, so a congregation that understands this nuance will be better equipped to design or upgrade their facility to reach optimal energy efficiency. One effective method to tackle with this so-called "off-peak" demand is to arrange a smaller space/zone or room for serving small services having less number of people. Figure 4.5 shows an example of such a space in a church building in Hong Kong. By doing this, both lighting energy and air conditioning load can be decreased significantly.

Figure 4.5 A smaller room for serving small services in a church

There is a need for flexible space to accommodate the various configurations and multiple uses to which church space is put. Efforts should be made to schedule cooling and lighting zones to coordinate with the actual activity schedules in the church. This can allow the engineering systems to be turned off in other parts of the facility that are not being used. Some churches have special places or rooms for the small children and youth clubs, where children and youth can run around and play games. The scheduling and operation of these rooms should take into account the requirements of energy efficiency.

4.2 Air Conditioning Systems

In Hong Kong, the first fully air-conditioned building (the demolished Hong Kong Bank Building in Central) was opened in 1935 (ASHRAE Hong Kong Chapter, 2010). Since then, application of air conditioning systems is developing fast and now they become a necessity and very common in most buildings including churches.

4.2.1 Air Conditioning for Churches

Traditionally, church buildings were designed and built with no air conditioning (see Section 2.2). However, in order to provide a comfortable environment for the users, air conditioning systems started to be applied and used in the churches in Hong Kong since 1960s. Figure 4.6 shows an old picture of the inauguration ceremony of air-conditioning system in a church building in Hong Kong in 1968. Nowadays, as found out in the case studies (Section 2.4), air conditioning constitutes the most significant part of electricity consumption in the church buildings.

Figure 4.6 Inauguration ceremony of air-conditioning system in a church building in Hong Kong in 1968 (Source: www.catholicheritage.org.hk)

Need not to say, using energy-efficient air-conditioners and smart use of air-conditioners will contribute significantly to reducing electricity consumption and greenhouse gas emissions in the church buildings. There is a large potential for improving energy efficiency in the design and operation of air conditioning systems because at present many churches are lacking the knowledge and commitment to tackle this issue. In some church buildings, there is also an urgent need to upgrade or retrofit the existing air conditioning and other building services systems because these systems are rather outdated. If energy performance and management are considered seriously in the respective church renovation projects, this will facilitate the work and enable better EMOs to be applied to the church buildings. Figure 4.7 shows examples of air conditioning equipment for a church building, including new window type air-conditioners (left) and an old air conditioning chiller plant (right).

Figure 4.7 Examples of air conditioning equipment for a church building

4.2.2 Design Considerations

In fact, adding air conditioning to churches can be difficult and challenging. The large spaces, particularly overhead, usage patterns ranging from packed congregations to small services, and window designs that may include large swaths of stained glass or no apertures at all present unique challenges. In addition, the historic nature of many churches may preclude traditional ductwork and equipment installation methods which might ruin the appearance of the beautiful ceiling and façades. If the church building has a highly pitched slate roofing material, it is often not possible to put the air conditioning packaged units on the roof. On the other hand, packaged units on the ground would have been unsightly with ductwork extending up the sides of the building; long window wells outside of the building made it difficult to locate large packaged units.

To resolve the above design limitations, it is necessary to first perform careful engineering analysis of the amount of cooling needed to cool the sanctuary so as to get accurate information for plant and equipment sizing. Instead of using standard packaged or split systems, the designer may consider to use ductless mini-split systems to overcome the appearance problems. Because the air handler portion of the ductless mini-split mounts right on the wall the designer can avoid having to run unsightly ductwork through the space. The new units can be mounted high on the wall out of the typical line of sight so they do not ruin the aesthetics of the space. The respective condensing units are small and therefore do not detract from the beautiful outside appearance of the building. To position the condensing units over the window wells, custom steel mounting platforms can be built for this purpose. If the mini-split air conditioning system can be independently zoned for different sections of the sanctuary, then it could respond to varying cooling needs within the large sanctuary.

4.2.3 Energy Management Factors

As in all air conditioning design, building size and functions, weather conditions and interior air circulation patterns are critical factors in controlling costs and optimising results (SMACNA, 1997). For the existing air conditioning systems, maintenance is a key concern. Although it is good stewardship and plain commonsense to keep the church's air conditioning systems in good working order, doing regular maintenance on them also increases their energy efficiency. For example, accumulated dirt and dust make the fans work harder and reduce airflow, therefore, the air filters should be cleaned or replaced regularly. Seasonal tune-ups and checking of the air conditioning equipment can avoid breakdowns and ensure good efficiency. Also, the air ducts and water piping shall be inspected for leakage or damaged insulation. Moreover, cooling energy can often be saved by proper individual temperature control for the spaces and optimum start/stop of the air conditioning system.

For new systems or retrofitting projects, it is possible to select the new advanced air conditioning systems which have higher equipment efficiency and system performance. For example, the use of high-efficiency variable refrigerant flow (VRF), multi-split and heat pump air conditioning systems is becoming more and more popular for churches. When the churches have constant swings in occupancy, they may consider demand-controlled ventilation (DCV) system which can save energy by decreasing the amount of outdoor ventilation supplied by the air conditioning system during low-occupancy hours. A DCV system senses the level of carbon dioxide (CO_2) in the return air stream and provides ventilation accordingly.

To optimise the energy conservation, it is important to properly size the equipment and consider the use of a DCV system, coupled with economizers (or free cooling), to meet the internal loads of the building. Sometimes, it is helpful to apply energy recovery ventilation systems to reclaim waste energy from the exhaust air stream and use it to condition the incoming fresh air. The use of variable speed drive (VSD) in fans and pumps will help improve the system efficiency during partload conditions. In some buildings, thermal energy storage systems can be employed to balance energy demand between peak/day time and off-peak/night time. With suitable weather conditions and operable windows, some churches can take advantage of natural ventilation or mixed-mode ventilation to minimise air conditioning energy use during the intermittent seasons (Autumn to Spring) in Hong Kong (Law, 2004); often it requires some design compromises as well as building occupants willing to tolerate temperature fluctuations.

4.3 Electrical Equipment and Appliance

As the amount of electrical equipment and appliances (e.g. room air conditioners, refrigerators, computers, LCD projectors, printers, photocopiers) found in church buildings and congregational facilities has increased, the amount of energy consumed by that equipment has also increased. Inefficient equipment not only draws power, but also emits heat that can contribute to higher air conditioning energy use. In Hong Kong, to facilitate the public in choosing energy efficient appliances and raise public awareness on energy saving, EMSD has set up a mandatory and a voluntary energy efficiency labelling scheme for appliances and equipment used in the home and office (www.energylabel.emsd.gov.hk). Figure 4.8 shows examples of the mandatory energy efficiency labels (for room air conditioner and CFL). Figure 4.9 shows examples of the voluntary energy efficiency labels.

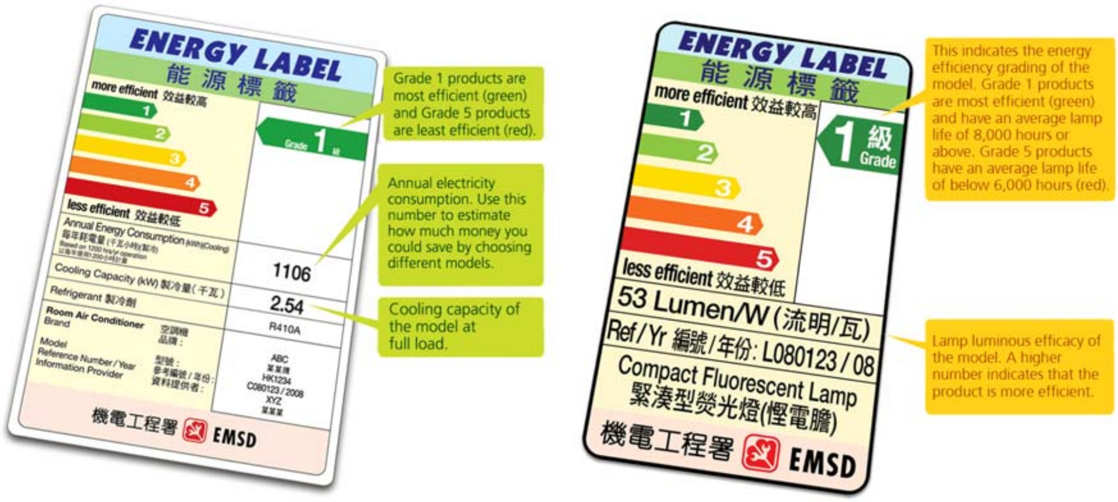


Figure 4.8 Examples of mandatory energy efficiency labels in Hong Kong (Source: EMSD)

Figure 4.9 Examples of voluntary energy efficiency labels in Hong Kong (Source: EMSD)

The energy label classifies the energy performance of a product type into five grades to help consumers in choosing energy efficient products. A product with Grade 1 energy label is among the most energy efficient in the market while a product with Grade 5 is least efficient. It is believed that significant energy saving could be achieved by using more energy efficient equipment and appliances in the church buildings. At present, there are 5 types of equipment under the mandatory energy efficiency labelling scheme, including room air conditioners, refrigerating appliances, compact fluorescent lamps, washing machines and dehumidifiers. There are 20 types of equipment and appliances under the voluntary energy efficiency labelling scheme (including grading-type and recognition-type).

4.4 Building Envelope

The building envelope, including windows, walls and roofs, serves as a thermal barrier and can affect the lighting, heating, and cooling needs of the building. In hot climate regions like Hong Kong, minimising heat transfer through the building envelope is crucial for reducing the need for space cooling.

4.4.1 Improve Window Systems

Window systems influence both the cooling and lighting requirements of a building. Nowadays, new materials, coatings, and designs have contributed to the improved energy efficiency of high-performing windows. Churches often have stained glass windows (see Figure 4.10 for an example). For new facilities or retrofit projects, it is possible to consider taking advantage of advancements in stain glass window technology. Today high performance low emissivity (low-e) insulated glass and thermally improved frames are available for many stained glass applications. Also, suitable sun shading devices and solar control design for the buildings can reduce solar heat gain and the corresponding cooling energy.

Figure 4.10 Stained glass windows used in a church in Hong Kong

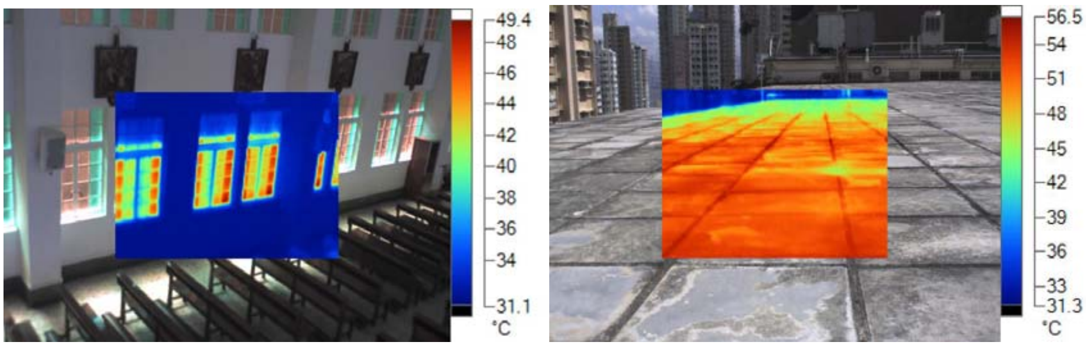
For existing windows, one may consider installing clear glass/plastic storm windows outside the stained glass to add an extra layer of protection against energy loss. If this is not possible, solar window film may be considered and applied to reduce solar heat gain and possibly block the ultra violet (UV) radiation to prevent it causing damage to the interior finishes and materials.

4.4.2 Walls and Roofs

The amount of energy lost or retained through walls or roofs is influenced by both design and materials. Design considerations affect the placement of windows and doors, the size and location of which can be optimised to reduce energy losses. Material selection and wall/roof insulation can affect the building's thermal properties and its ability to store heat.

Firstly, adding insulation strategically will improve the efficiency of the building; however, it is only effective if the building is properly sealed. Sealing cracks and leaks prevents air flow and is crucial for effective building envelope insulation. Figure

4.11 shows the use of infra-red photos to examine the temperature of building envelope in the church buildings. This technique can be used in the energy audit process (see Chapter 3) to identify thermal bridges and air leakage of the building envelope. Secondly, thermal mass buildings absorb energy more slowly and then hold it longer, effectively reducing indoor temperature fluctuations and reducing overall cooling and heating requirements and peak demands. Thermal mass materials include traditional materials, such as stone and adobe, and cutting edge products, such as those that incorporate phase change materials (PCMs).



(a) External windows and walls *(b) Roof surface*

Figure 4.11 Infra-red photos to examine the temperature of building envelope

4.4.3 PV and Green Roofs

In addition, roofs also offer several opportunities for installing environmentally friendly systems such as solar energy and green roof systems (see also Section 5.3). For example, solar photovoltaic (PV) systems can either be installed as a rooftop array on top of the building or a building-integrated photovoltaic system can be integrated into the building as roofing tiles or shingles. The on-site PV electricity generation can help reduce the reliance on fossil energy.

It is found from the case studies in Hong Kong (Section 2.4) that some churches have available roof spaces that can be used for green roofs or roof gardens. Figure 4.12 shows the roof spaces in the church buildings. Green roof systems could contribute positively to the mitigation of urban heat island and enhancement of building thermal and environmental performance (Hui, 2006).

Figure 4.12 Roof spaces in the church buildings in Hong Kong

5. Major Considerations

To achieve successful outcomes and results, both technology and people must be focused in building energy management and assessment. When it comes to implementing and managing an energy conservation programme for church buildings, a heavy emphasis is on the people factor because the stakeholders will determine the goals, actions and progress. Figure 5.1 indicates the important steps for energy management and can form a strategic framework for the work. It should be noted that the final goal of energy management is to develop energy assessment as a process of continuous improvement rather than as a series of individual audit actions. To succeed in this kind of development, the PDCA circle (Plan-Do-Check-Act) must be followed and new possibilities for improving energy efficiency should be assessed regularly. The feedback and re-assess routes on Figure 5.1 show this character.

Figure 5.1 Important steps for energy management (Source: www.energystar.gov)

5.1 Commitment to Energy Efficiency

The commitment to energy efficiency for church buildings can be classified into three main areas, namely: organisational commitment, technological commitment and commitment to behavioural change (Climate Change Centre, 2006). Table 5.1 explains the details of each one. By adopting an energy management and conservation policy in the church body, it can recognise energy efficiency as a high-priority energy resource and make a strong, long-term commitment to implement cost-effective energy efficiency measures. To ensure effective implementation, the benefits of and opportunities for energy efficiency should be broadly communicated to their volunteers and contractors. Also, the church should agree a champion to lead the work to manage energy and emissions.

Table 5.1 Commitment to energy efficiency for religious buildings [adapted from Climate Change Centre (2006)]

Organisational Commitment	• The more people who commit to action within a place of worship, the stronger the project. Having a project champion(s) is essential. • Concerted action within an organisation will lead to more resources, ideas, and creative ways to move forward on energy efficiency. • Time may be needed to get consensus, but it will be worth it.
Technological Commitment	• When doing retrofits, there is a good chance that new technology will have to be purchased, such as energy efficient lighting, weatherstripping, or a new chiller. • Commitment to technological change (along with the financial planning for such changes) is essential.
Commitment to Behavioural Change	• If people have poor energy management habits (such as leaving lights on), it takes away from the benefits of retrofitting. • Educating and inspiring the congregation to change behaviour is therefore an important step.

If the church building is self-owned, then the commitment should be clearly set up through internal policies led by the senior management board. If the church building is borrowed or rented, it is necessary to check if the host or landlord already has the relevant commitment. If yes, the document should be studied to verify and coordinate with the goals of the church. If no, discussion should be carried out to decide an appropriate method for developing the commitment.

5.2 Finding Funds

Usually churches are non-profit organisations and their primary income is the donations and tithes of their members. Some of them might apply for and get a grant from their parent congregation or council, a charity foundation or a government department. The church governors should understand the great responsibility of demonstrating good stewardship of those financial contributions. Normally a church can secure money for retrofit or energy conservation projects in one of the following ways:

- Saved funds (based on the money on hand that can be spent).
- Raised funds (e.g. through a specific stewardship campaign).
- Borrowed funds (e.g. banks and bonds). Various factors influence the amount of borrowed money.

Access to capital for an energy-efficiency upgrade need not be an issue. Some upgrades require little funding. For those that do require investment, there are many traditional and non-traditional financial resources available. A well-designed upgrade can provide a positive cash flow from energy savings while paying off the investment for new equipment. For small, inexpensive projects, it is possible to use the church's own internal funds to pay for the upgrade. Depending on the congregation's finances, this could come from the savings, operating budget, or funding raising initiatives. For larger jobs, financing might be the only way to pay for the upgrade. Fortunately, a variety of sources and mechanisms exist to help finance energy-efficiency improvement projects.

It is important to weigh the competing needs for funds versus continuing increases in operating costs for energy. Even a long-term investment on energy efficiency results in affordable comfort, and new, more reliable equipment that will pay for itself with energy savings. Strategic energy-efficiency investments are the hedge to offset potential losses/gains if the higher utility bills cannot be controlled. The following resources can help the church find funding information and opportunities for the proposed upgrade:

(a) Assess the Savings Potential. We cannot see energy, so it can be difficult to visualise the potential savings lying undiscovered in the facility. However, one can see and easily understand those utility bills received each month. If the energy bill can be lowered by say 30%, the potential energy savings can be financial resources that could go to worthwhile projects instead of to the local utility.

(b) Financial Analysis. It always pays to do the homework before investing in energy-efficient equipment. What products and equipment really work? How much will it cost to install? Where do you find the money? How quickly will you recover your investment? There are many resources to help people get the answers that will work for their congregation.

(c) Performance Contracting. As an alternative to implementation of EMOs, the building owner can employ a performance contracting service provider to do the work. The concept of performance contracting is that the service provider will design and implement the EMOs at a cost of a certain percentage of the total savings resulted from implementation of these EMOs.

5.3 Environmentally Friendly Church

Making the churches a more environmentally friendly place can provide a healthy, toxic-free sacred space as well as help protect God’s creation for current and future generations. There is no one way for a church to become green. Every congregation has different strengths and is called to meet different needs.

Energy is the first step to green. When considering the green or environmentally friendly attributes of a building, energy efficiency should come first. But energy saving is just one of a range of environmentally responsible actions that churches should take in response to God’s command to care for the earth (Kung Kao Pao, 2006). Other green actions to consider include reduction and recycling of waste, using locally-produced and fairly traded foods, reducing car travel, conserving water, installing solar panels and applying green roofs (Eco-congregation, 2009).

Many churches are becoming more eco-friendly, as this can help reduce costs for churches as well as help improve the Earth. In fact, how church buildings make good use of wind, sunlight and water to achieve environmental protection is an art of communication between men and nature. Besides energy efficiency, the main areas of concern include site environment, renewable energy, water efficiency, materials and indoor environmental quality. Table 5.2 gives some examples of design strategies for green church buildings under these headings.

Table 5.2 Design strategies for green church buildings

Site environment • Locate near public transit • Prefer brownfield site • Design green roofs and walls • Reduce light pollution **Renewable energy** • Solar thermal (for hot water) • Solar photovoltaics (PV) • Wind turbines • Geothermal **Water efficiency** • Low-flow toilets and low-flush urinals • Flow restrictors on taps • Rain water harvesting • Grey water recycling	**Materials** • Reuse existing building/structure • Select recycled/renewable materials • Use local/regional materials • Design for disassembly **Indoor environmental quality** • Increase outdoor air ventilation • Use non-toxic paints & products • Select low VOC (volatile organic compounds) materials • Promote natural daylight

5.4 Education and Spiritual Study

Using the Bible definition, a “church” is not a building; it is the Christians who meet there. The building of a church facility is a very practical thing, and we need to be very practical about our approach to be successful. If we are successful in a practical sense, then the opportunity is there for the ministry of a particular church body to grow and, therefore, be successful in the spiritual sense as well.

To fulfil the practical and spiritual goals of energy management, it is important to establish the education and training in the churches. Energy education offers a people-based managing and consulting function designed to change behaviours and to correct habits that had become part of the operation. Training and support can be provided to create the “attitude of awareness” that is primary to this people-oriented programme. This is also the time to assess the needs and the conservation opportunities of each area to educate staff and volunteers, and to measure and track the progress of the programme.

One way to develop the education and training is to let the youth group of the church help do an initial church energy audit, based on the last year’s utility bills and a facility inspection, and let them use next year’s cost savings for their summer mission trip. Apart from the ideas to engage the youth group, it would also be beneficial to devote a night of study to the spiritual side of why they should be concerned for the energy and environment. Forums and brainstorming sessions may be organised to identify areas of inefficiency and to develop new ideas for energy saving. All in all, the energy assessment and improvements of the church building can serve as educational experience for adults and children because it can create a level of motivation and participation for all age groups. The whole process can give people good learning opportunities for liturgical and stewardship education.

6. Conclusions

There is no doubt that global warming and climate change are really under way, with potentially disastrous consequences for all life on Earth. The principal cause is the use of energy, which puts more pollution into the upper atmosphere. Energy saving constitutes a primary measure for the protection of the environment; our response to global climate change should be a sign of our respect for God's creation. It is believed that a big part of flourishing churches is in the area of environmental stewardship and the energy management of church buildings can enhance this belief. Energy efficiency not only could make the building's resources more desirable, but also would reduce energy cost and operating expenses of the church.

It is found that over 75% of the churches in Hong Kong are located inside commercial, residential and school buildings; there are also some stand-alone church buildings which have historic value to architectural conservation. In order to carry out the energy audit effectively, it is important to understand the characteristics and operation of the church buildings. By studying a few examples of churches in Hong Kong and the experience in other countries, useful information has been established to evaluate the energy audit process and identify energy management opportunities.

6.1 Potential of Energy Conservation

This research focuses on some 1,250 church buildings established by Christianity in Hong Kong. It is found that the main energy conservation potential is related to the design, operation and management of the lighting and air conditioning systems. When applying energy audit to church buildings, attention should be drawn to the architectural design and layouts, building operation and functions, heritage conservation and the liturgical spirit and norms. Most churches use the entirety of their facilities only a few days a week, so a congregation that understands this nuance will be better equipped to design or upgrade their facility to reach optimal energy efficiency. The results from the energy assessment can be exploited in retrofit design when energy efficiency improvements are considered in connection with a major renovation for the church buildings.

It is believed that the research findings and results could be useful to the church buildings in other countries. Also, the principles of energy assessment and management could be applied to the houses of worship and buildings of other religious groups in Hong Kong. In fact, there are a large variety of religious groups in Hong Kong, including Buddhism, Taoism, Confucianism, Christianity, Islam, Hinduism, Sikhism and Judaism (HKSAR Government, 2012). As of 2010 the region is home to approximately 1.5 million Buddhists, 1 million Taoists, 480,000 Protestants, 353,000 Roman Catholics, 220,000 Muslims, 40,000 Hindus, 10,000 Sikhs, and other smaller communities. All of these groups have a considerable number of adherents. For example, at present Hong Kong has approximately 600 temples, shrines and monasteries. Energy management programmes could be developed and applied to these buildings too.

6.2 Major Recommendations

It is recommended that:

(a) Each congregation shall assemble an energy management team responsible for tracking energy use, formulating and coordinating an energy conservation programme, documenting savings achieved, and educating the congregation about energy efficiency at church and at home.

(b) Energy accounting and information systems shall be developed and promoted to the churches in order to provide feedback on how much energy they use, and how much it costs. The systems also provide a means to effectively communicate energy data that facility staff, building occupants and managers can use to improve cost management.

(c) A high-level energy management and conservation policy shall be set up in the church body to express the commitment to energy efficiency.

(d) The church's procurement policy of electrical equipment and appliances shall be set up to ensure only efficient equipment and products will be taken in the future.

(e) Energy audit forms and guidelines for church buildings shall be developed. Reference can be made to the guidebooks in other countries, such as Climate Change Centre (2006), KAIROS (2004) and MCGB (2010).

(f) Energy performance and management shall be considered seriously in church renovation projects.

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Appendix I – Buildings Energy Efficiency Ordinance (BEEO) in Hong Kong

The new Buildings Energy Efficiency Ordinance (BEEO) (Cap. 610) (www.beeo.emsd.gov.hk) has come into full operation in Hong Kong on 21 September 2012. This Ordinance mandates the minimum energy performance standards for four major types of building services installations and energy audits in specified buildings. The three key requirements of the Ordinance are:

- The developers or building owners of newly constructed buildings should ensure that the four key types of building services installation (namely, air-conditioning installation, lighting installation, electrical installation as well as lift and escalator installation) comply with the design standards of the Building Energy Code (BEC).
- The responsible persons (i.e. owners, tenants or occupiers etc.) in buildings should ensure that the four key types of building services installation therein comply with the design standards of the BEC when “major retrofitting works” are carried out.
- The owners of commercial buildings (including the commercial portions of composite buildings, e.g. shopping malls under residential storeys) should carry out energy audit for the four key types of central building services installation therein in accordance with the Energy Audit Code (EAC) every 10 years.

First Energy Audit

The period within which the first energy audit must be carried out depends on the age of the building. A summary of the schedule is shown below.

Issue date of occupation permit	First audit must be carried out
On or after 1 January 1988	1 year after August 2012 (i.e. 20 Sep. 2013)
After 31 December 1977 but before 1 January 1988	2 year after August 2012 (i.e. 20 Sep. 2014)
After 31 December 1969 but before 1 January 1978	3 year after August 2012 (i.e. 20 Sep. 2015)
On or before 31 December 1969	4 year after August 2012 (i.e. 20 Sep. 2016)

The owners of commercial buildings or commercial portions of a composite building are required to arrange energy audits for the central building services installations at least once every ten years. An energy audit must be carried out by a registered energy assessor (REA) who is to issue an Energy Audit Form and send a copy of such form and an energy audit report to the EMSD within 30 days after issuing the Energy Audit Form. The owner of a building in respect of which an Energy Audit Form is in force must exhibit a copy of the Form in a conspicuous position at the main entrance of the building.

The new commercial buildings or the commercial portions of new composite buildings are required to carry out the first energy audit within 10 years after the buildings are first issued with a Certificate of Compliance Registration.

Renewal of Energy Audit Form and Liability

The Energy Audit Form is valid for 10 years starting from the completion date of the energy audit. Before the expiry of Energy Audit Form, the owner is required to reserve adequate time to engage a REA to complete another energy audit and obtain a new valid Energy Audit Form which should be exhibited in a conspicuous position at the main entrance of the building.

If non-compliance is identified, the EMSD may issue an improvement notice to the relevant persons of that building/unit/common area (e.g. developer, the Incorporated Owners, owner, tenant or occupier etc.) before prosecution and direct those persons to remedy the contravention within the period specified in the notice. The notice will contain directions about measures to be taken. The basic information, including issue date, building name and address etc., of each notice will be published at the EMSD's website. Once the contravention in a notice has been remedied, the information of the notice will be removed from the relevant list at the EMSD's website.

According to the BEEO, if the owner of a commercial building or the commercial portion of a composite building contravenes the requirements, that person may be liable to prosecution.

Appendix II – Historical Church Buildings in Hong Kong (Grade 1 to 3)

(as of 21 September 2012)

(a) Hong Kong Island

	Name	Address	Grade	Built Yr
1	香港天主教聖母無原罪主教座堂 The Hong Kong Catholic Cathedral of Immaculate Conception	香港中環堅道16號 No. 16 Caine Road, Central, HK	Grade 1	1888
2	聖心教堂 Sacred Heart Chapel	香港中環堅道36號A No. 36A Caine Road, Central, HK	Grade 1	1907
3	基督科學教會香港第一分會 First Church of Christ Scientist	香港中環麥當奴道31號 No. 31 MacDonnell Road, Central, HK	Grade 2	1912
4	中華基督教會合一堂(香港堂) The Church of Christ in China Hop Yat Church (Hong Kong Church)	香港半山般咸道2號 No. 2 Bonham Road, Mid-Levels, HK	Grade 1	1926
5	聖安多尼堂 St. Anthony's Catholic Church	香港薄扶林薄扶林道69號A 69A Pokfulam Road, Pok Fu Lam, HK	Grade 2	1953
6	基督教香港崇真會救恩堂 Tsung Tsin Mission of Hong Kong Kau Yan Church	香港西營盤高街97號A No. 97A High Street, Sai Ying Pun, HK	Grade 1	1932
7	聖保羅堂 St. Paul's Church	香港中環己連拿利76號 No. 76 Glenealy Road, Central, HK	Grade 1	1911
8	聖保祿修院 St. Paul's Convent Church	香港銅鑼灣銅鑼灣道 Tung Lo Wan Road, Causeway Bay, HK	Grade 1	1928
9	聖瑪加利大堂 St. Margaret's Church	香港銅鑼灣樂活道2號A No. 2A Broadwood Road, Causeway Bay, HK	Grade 1	1923
10	聖公會聖瑪利亞堂 S. K. H. St. Mary's Church	香港銅鑼灣道2號A No. 2A Tung Lo Wan Road, Causeway Bay, HK	Grade 1	1937
11	聖瑪加利大堂 St. Margaret's Church	香港銅鑼灣樂活道2號A No. 2A Broadwood Road, Causeway Bay, HK	Grade 1	1923
12	聖保祿修院 St. Paul's Convent Church	香港銅鑼灣銅鑼灣道 Tung Lo Wan Road, Causeway Bay, HK	Grade 1	1928
13	中華基督教會聖光堂 Shing Kwong Church, Church of Christ in China	香港銅鑼灣東院道7號 No. 7 Eastern Hospital Road, Causeway Bay, HK	Grade 3	1927
14	香港墳場教堂 Hong Kong Cemetery, Chapel	香港跑馬地黃泥涌道 Wong Nai Chung Road, Happy Valley, HK	Grade 1	1845
15	聖彌額爾天主教墳場聖彌額爾小堂 St. Michael's Catholic Cemetery, St. Michael's Cemetery Chapel	香港跑馬地黃泥涌道 Wong Nai Chung Road, Happy Valley, HK	Grade 2	1916
16	猶太墳場小教堂 Jewish Cemetery, Chapel	香港跑馬地山光道13號 No. 13 Shan Kwong Road, Happy Valley, HK	Grade 3	1857
17	聖神修院小教堂 Holy Spirit Seminary, Chapel	香港黃竹坑惠福道6號 No. 6 Welfare Road, Wong Chuk Hang, HK	Grade 3	1956
18	聖士提反書院聖士提反堂 St. Stephen's College, St. Stephen's Chapel	香港赤柱東頭灣道22號 No. 22 Tung Tau Wan Road, Stanley, HK	Grade 3	1950

(b) Kowloon

1	聖安德烈堂全址 St. Andrew's Church Compound	九龍尖沙咀彌敦道138號 No. 138 Nathan Road, Tsim Sha Tsui, KLN	Grade 2	1910
2	玫瑰堂 Rosary Church	九龍尖沙咀漆咸道南125號 No. 125 Chatham Road South, Tsim Sha Tsui, KLN	Grade 1	1905
3	聖公會基督堂 S. K. H. Christ Church	九龍九龍塘窩打老道132號 No. 132 Waterloo Road, Kowloon Tong, KLN	Grade 3	1938
4	諸聖堂 All Saints' Church	九龍旺角染布房街2號 No. 2 Yim Po Fong Street, Mong Kok, KLN	Grade 3	1928
5	九龍佑寧堂 Kowloon Union Church	九龍油麻地佐敦道4號 No. 4 Jordon Road, Yau Ma Tei, KLN	Grade 3	1931
6	聖德肋撒堂 St. Teresa's Church	九龍太子道西258號 No. 258 Prince Edward Road West, KLN	Grade 1	1932
7	聖公會聖三一堂 S. K. H. Holy Trinity Church	九龍馬頭涌道135號 No. 135 Ma Tau Chung Road, KLN	Grade 2	1937
8	協恩中學教堂 Heep Yunn School, St. Clare Chapel	九龍何文田農圃道1號 No. 1 Farm Road, Ho Man Tin, KLN	Grade 3	1957

(c) New Territories

1	崇謙堂 Tsung Kyam Church	新界粉嶺龍躍頭崇謙堂村20A號 No. 20A Shung Him Tong Tsuen, Lung Yuek Tau, Fanling, N.T.	Grade 3	1927
2	聖約瑟堂教堂 St. Joseph's Church, Church Building	新界粉嶺聯和墟和泰街5號 No. 5 Wo Tai Street, Luen Wo Hui, Fanling, N.T.	Grade 3	1953
3	聖約瑟堂活動室 St. Joseph's Church, Activity Block	新界粉嶺聯和墟和泰街5號 No. 5 Wo Tai Street, Luen Wo Hui, Fanling, N.T.	Grade 3	1953
4	聖約瑟堂神父宿舍 St. Joseph's Church, Father's Residence	新界粉嶺聯和墟和泰街5號 No. 5 Wo Tai Street, Luen Wo Hui, Fanling, N.T.	Grade 3	1953
5	聖伯多祿聖保祿堂 Ss. Peter and Paul Church	新界元朗青山公路201號 No. 201 Castle Peak Road, Yuen Long, N.T.	Grade 3	1958
6	聖若望小堂 St. John's Chapel	新界元朗八鄉長莆2號 No. 2 Cheung Po, Pat Heung, Yuen Long, N.T.	Grade 2	1928
7	聖母無原罪小堂 Immaculate Conception Chapel	新界西貢大浪 Tai Long, Sai Kung, N.T.	Grade 3	1867
8	聖約瑟堂 St. Joseph's Chapel	新界西貢鹽田仔 Yim Tin Tsai, Sai Kung, N.T.	Grade 2	1890
9	聖母無玷之心小堂 Immaculate Heart of Mary Chapel	新界大埔白沙澳 Pak Sha O, Tai Po, N.T.	Grade 3	1923

Appendix III – No or Low Cost Energy Saving Measures for Church Buildings

The following information provides examples of no or low cost simple housekeeping measures (EMO Category I or II) which can be carried out easily to kick start an energy management programme for church premises and schools.

1. <u>Air Conditioning (AC)</u>

1.1 Minimise Energy Use
- Turn off AC right after use – affix "Save Energy" sticker near the exit
- Use natural ventilation or fan where possible (to minimise the use of AC)

1.2 Use Energy Efficiently
- Set AC thermostat temperature at 24 ºC and suitable fan speed
- Set up maintenance programme to ensure efficient operation
- Clean AC and dust filter at suitable frequencies
- Replace room coolers with more energy efficient models (with Grade 1 or 2 Energy Label)

1.3 Minimise Energy Loss
- Keep windows and doors closed to minimise air infiltration
- Lower window blinds to reduce direct sunlight in Summer

2. <u>Lighting</u>

2.1 Hardware Efficiency
- Replace light fittings with more energy efficient lamps (e.g. CFL and LED)
- Install or replace higher efficient ballasts for fluorescent lighting
- Consider LED exit signs to replace fluorescent ones

2.2 Usage Efficiency
- Turn off unnecessary lighting for area not in use – affix "Save Energy" sticker near the switch
- Turn off or dim lighting in perimeter area

3. <u>Office Equipment</u>

3.1 Hardware Efficiency
- Replace CRT monitors with LCD monitors
- Replace old electrical appliances with more energy-efficient models with Energy Label
- Identify and replace faulty equipment e.g. flickering lights, noisy fans and leaking water AC

3.2 Usage Efficiency
- Set all computers and office equipment to "energy saving" mode. And turn them off after use
- Unplug equipment chargers and adapters when not in use
- Arrange for last-man-out to turn off all equipment

4. Lifts & Escalators

4.1 Hardware Efficiency

- Specify lift and escalator systems with energy efficient measures

4.2 Usage Efficiency

- Use the stairs for 1 or 2 floors up or down – affix "Save Energy" sticker near the lift
- Shut down some of the lifts during non-peak hours and their lighting & ventilation systems

5. Facility Management

- Keep windows and doors shut for all AC areas
- Avoid pre-cooling. Use "high" fan mode instead of lowering the temperature
- Turn off some lighting and AC units when occupancy is low or during non-peak hours
- Turn off AC and lighting right after use
- Turn off AC, unnecessary lifts and escalators when the venue is closed
- Turn on exterior lighting only when necessary

Appendix IV – Simple Energy Audit for Church Buildings

Start the energy audit process on your own. The following church energy audit suggestions are so simple and straightforward that a church's youth group can perform them. Give the youth group a day to explore your facilities for increased efficiency opportunities, and then let them get started making some of the easiest changes that will contribute to your congregation's care of creation.

<u>Steps to an Energy Efficient Church</u>

- Find out who is responsible for the electricity bills and air conditioning and lighting controls in your church. Ask yourself if it would be worthwhile appointing an Energy Manager to take responsibility for this.
- Undertake an energy audit so you can understand when your energy is being used. There are various organisations that can help with this.
- Once you have identified the problem areas put together an action plan to start tackling them. They don't have to be completed straight away and many actions can be undertaken as part of the church's maintenance programme.

<u>Audit</u>

Review your church's utility bills for the last year and determine in which areas your congregation would most benefit from greater efficiency. Take a tour through your church's buildings and look for the following:

- Lights that are often kept unnecessarily illuminated
- Lights using incandescent light bulbs or inefficient lamps (such as T8 fluorescent)
- The orientation of windows and opportunities to utilize natural light
- The thermostats that the air conditioning rely on and the temperature to which they are set
- Outside doors that are often left open unnecessarily
- Air leaks at doors and windows where outside air is entering the building
- Electrical appliances (computers, printers, copiers, lamps, TVs, DVRs, etc.) that remains plugged in and/or on all the time
- Electrical appliances that do not have energy efficiency labels or the grade is not good enough

Fix it

Spend some time making immediate changes as appropriate, or crafting a plan for regularly and incrementally reducing the facilities' energy use.

- Replace incandescent light bulbs with compact fluorescent lamps. CFLs cost about 75% less than incandescent light bulbs to operate, and they last up to ten times longer.
- Turn off or make a plan to turn off lights that are not in use. Install switch plate occupancy sensors where appropriate, to avoid using lights in spaces that aren't always occupied.
- Replace cracked weather-stripping along doors, and caulk or re-caulk around windows if it appears that outside air is seeping in through gaps. Purchase and install foam insulation for outlets, and place plastic plugs in unused sockets, for both safety and energy efficiency.
- Utilize natural light and ventilation, reducing electric lighting and cooling accordingly. In summer, cover windows from the heat of the sun to avoid turning the air conditioning too high. In winter, let the sun provide heat and light through these windows.
- Purchase programmable thermostats and program them according to the needs of the church spaces over the course of the week. Turning the air conditioning no lower than 25 ºC will dramatically cut your air conditioning bills. Use fans, rather than central air conditioning, as much as possible. Air circulation ultimately has a more cooling effect than artificially cooling still air.
- Unplug appliances that don't need to be in use at all times. To make this easier, place a number of appliances in the same area on a powerstrip, and turn this off when those appliances aren't in use. Make sure that anything with a "ready" light (computers, printers, TVs, coffeemakers, etc.) is turned completely OFF when not in use. Screen savers on computers save nothing. Turning computers completely off creates a great reduction in energy use.
- Installing appliances and equipment with Grade 1 or recognition energy label will reduce your energy costs. When older equipment requires replacement, install new equipment with suitable grade energy label.

Appendix V – Useful Websites and Resources

Hong Kong Churches:

Catholic Diocese of Hong Kong (天主教香港教區), www.catholic.org.hk
Catholic Heritage (天主教香港教區歷史建築探索), www.catholicheritage.org.hk
Hong Kong Catholic Diocese Archives (香港天主教教區檔案處),
http://archives.catholic.org.hk/
Hong Kong Diocesan Liturgy Commission (香港教區禮儀委員會),
www.catholic-dlc.org.hk
www.catholic-liturgy.org.hk
The Church in Hong Kong (香港教會), www.churchinhongkong.org
Hong Kong Church Renewal Movement Ltd. (香港教會更新運動), www.hkchurch.org
Catholic Messengers of Green Consciousness (CMCG) (天主教綠識傳人),
www.greenmessengers.org
Christians for Eco-concern (基督徒環保關注組),
http://christians4ecoconcern.blogspot.hk/

List of Catholic churches in Hong Kong – Wikipedia,
http://en.wikipedia.org/wiki/List_of_Catholic_churches_in_Hong_Kong
Places of worship in Hong Kong – Wikipedia,
http://en.wikipedia.org/wiki/Places_of_worship_in_Hong_Kong
Christianity in Hong Kong – Wikipedia,
http://en.wikipedia.org/wiki/Christianity_in_Hong_Kong

Hong Kong Building Energy Efficiency:

Buildings Energy Efficiency Funding Schemes, www.building-energy-funds.gov.hk
Buildings Energy Efficiency Ordinance, www.beeo.emsd.gov.hk
EMSD – "Promoting Energy Efficiency and Conservation",
http://www.emsd.gov.hk/emsd/eng/pee/index.shtml
EnergyLand, EMSD, www.energyland.emsd.gov.hk
Energy Management: Publications, EMSD,
http://www.emsd.gov.hk/emsd/eng/pee/em_pub.shtml

Environment and Conservation Fund (ECF), www.ecf.gov.hk
Environmental Protection Department – "Climate Change",
http://www.epd.gov.hk/epd/english/climate_change/index.html

HK Sustainable Technology Net, http://sustech.emsd.gov.hk
HK EE Net, http://ee.emsd.gov.hk
HK RE Net, http://re.emsd.gov.hk
HK Green Building Technology Net, http://gbtech.emsd.gov.hk

Hong Kong Association of Energy Service Companies (HAESCO), www.haesco.hk

Mandatory Energy Efficiency Labelling Scheme, www.energylabel.emsd.gov.hk
Registered Energy Assessor (REA), www.beeo.emsd.gov.hk/en/mibec_app.html

International:

Alliance of Religions and Conservation, www.arcworld.org
Carbon Trust, www.thecarbontrust.co.uk
Christian Ecology Link, www.christian-ecology.org.uk
Church Care (UK), www.churchcare.co.uk
Church Construction, www.churchconstruction.com
Churches & Houses of Worship, http://home1.gte.net/mjarzo/church1.htm
- Resource Guide for Planning and Design of Church Facilities

Eco-congregation (England & Wales), http://ew.ecocongregation.org
Eco Faith (UK), www.ecofaith.co.uk
Green Church Association, www.greenchurchassociation.org
Green Church Project, www.greenchurchproject.org/
Green Churches, nccecojustice.org/greenchurch/
KARIOS Canada, www.kairoscanada.org
Operation Noah, www.operationnoah.org
Project Green Church, www.mjuniting.org.au/greenchurch/
The Methodist Church of Great Britain, www.methodist.org.uk

Churches ... different types of Christian, http://www.request.org.uk/main/churches/churches.htm
Church architecture – Wikipedia, http://en.wikipedia.org/wiki/Church_architecture
Church Architecture Network, www.churcharchitecture.net
Church (building) – Wikipedia, http://en.wikipedia.org/wiki/Church_(building)

Energy Efficient Lighting (selection of CFL and LED lighting), http://eartheasy.com/live_energyeff_lighting.htm