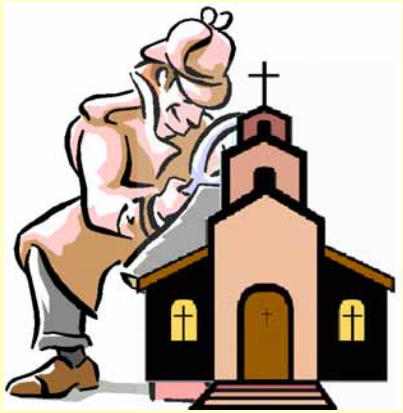
ASHRAE-HKC/CIBSE-HKB/HKIE-BSD Joint Technical Seminar
20 Dec 2012 (Thu), HKIE Headquarters

Energy Audit and Energy Management for Church Buildings in Hong Kong
香港的教堂建築之能源審核和能源管理



1911-2011

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- The churches we have visited

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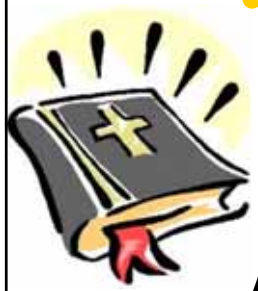
- Major Considerations 主要考慮因素
- Conclusions 結論

Introduction 引言

- Churches can help to protect the environment and tackle the climate change issue 教會可以幫助保護環境和應對氣候變化問題
  - Genesis 2:15 – "The God took the man and placed him in the garden to till it and keep it"



創世記 2:15 – 耶和華 神將那人安置在伊甸園、使他修理看守。

  - Our planet is *God's creation*, the planet Earth is given to us as the source of life but; we have the responsibility to look after *our environment*

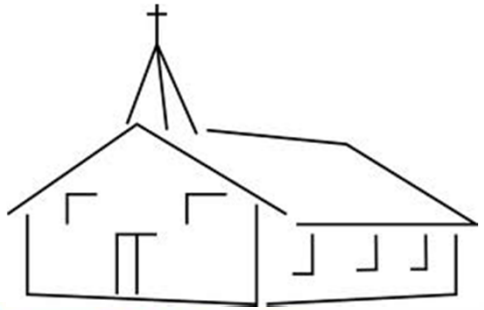
Introduction 引言

- Reducing the church's energy use 減少了教會的能源使用可以
  - Save money 省錢
  - Decrease greenhouse gas emissions
    減少溫室氣體排放
  - Help protect our environment
    幫助保護我們的環境
  - Honour our relationship with God's creation
    表揚神的創造與我們的關係

Introduction 引言

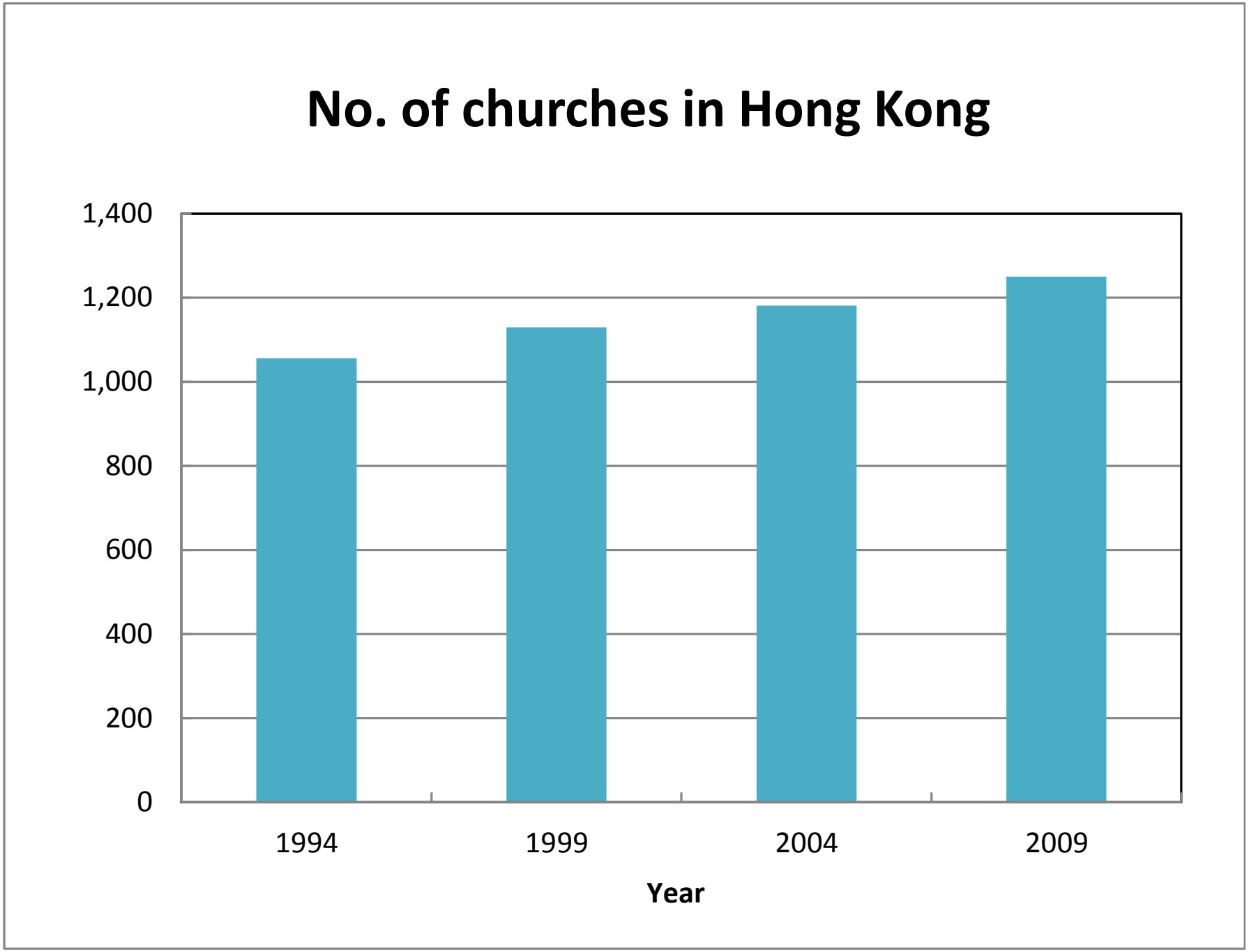
- Objectives of this research study:
  - To investigate the energy audit process and energy management opportunities for church buildings in Hong Kong
  - To develop practical information and guidelines for promoting energy conservation
- 本研究的目標：
  - 探討香港的教堂建築能源審核的過程和能源管理機會
  - 為推進節能減排制定切實可行的信息和指導方針

Church Buildings in HK
香港的教堂建築



- Established by Christianity in HK since 1841
  基督教1841年以來在香港成立
- In 2011, about 843,000 Christians 基督徒
  - Protestant 基督教新教徒: 480,000
  - Catholics 天主教徒: 363,000
- Total about 1,250 churches 總計約1,250教堂
  - Also, church-run schools, social service centres, health care facilities 此外，教會辦的學校，社會服務中心，衛生保健設施

Number of churches in HK 在香港的教堂數目 (1994-2009)



[Data Source: Wu and Lee (2010), 《2009香港教會普查簡報》]

Types of church buildings and setting methods 教堂類別和設置方式

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)

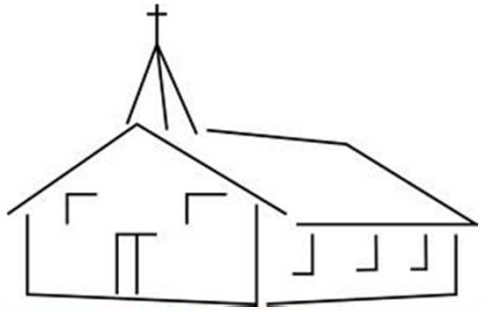
Table 2.2 Percentage of the methods of setting the church buildings in Hong Kong

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)

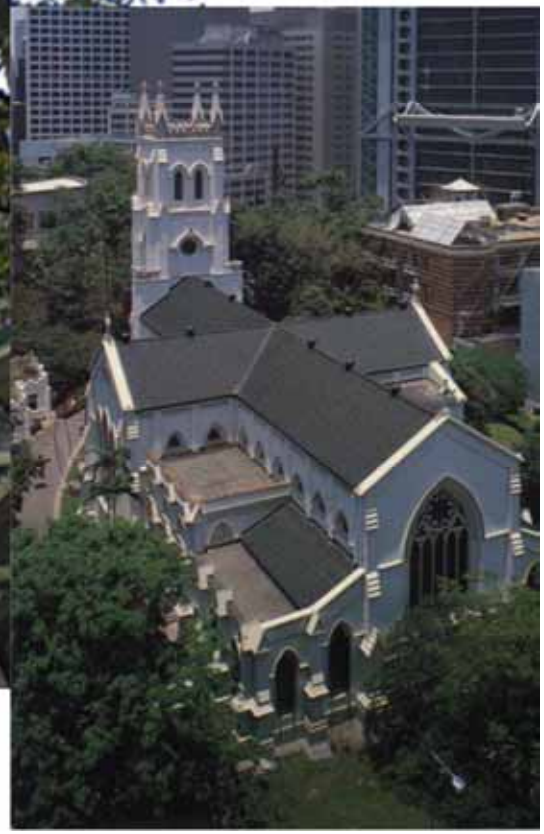
[Data Source: Wu and Lee (2010), 《2009香港教會普查簡報》]

Church Buildings in HK
香港的教堂建築



- Typical church buildings 典型的教堂建築
  - Assembly hall, offices and activity rooms
  - Main functions: assembling, worshipping christenings, gatherings, meetings, school activities, weddings and funerals
  - Some are historic heritage buildings
- Traditional church design 傳統的教堂設計
  - Facing east, in the shape of a cross
  - Have a large vaulted space in assembly hall

A historical church building in HK 香港一座歷史悠久的教堂建築*



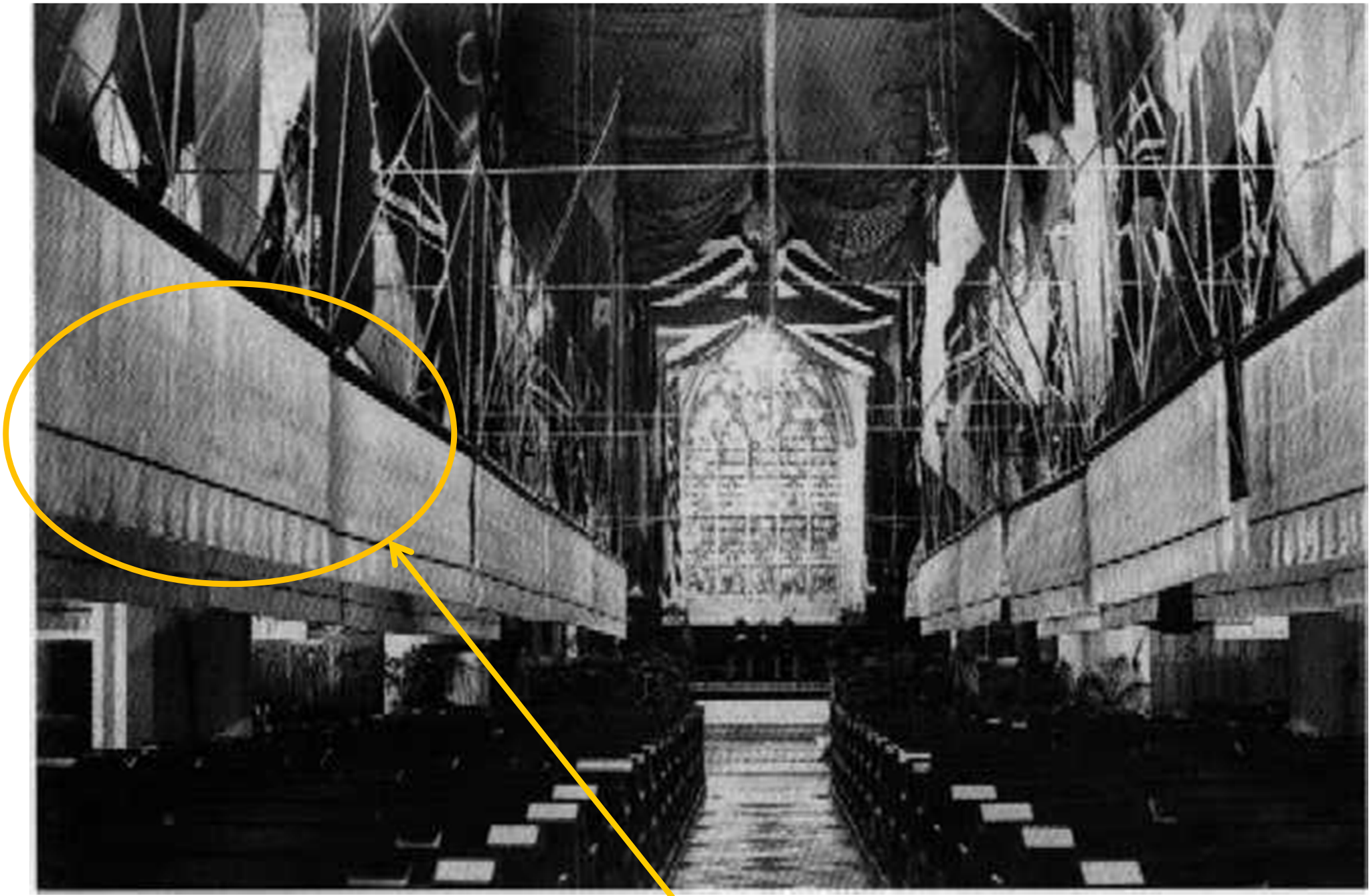
* Hong Kong St John's Cathedral (video, 2:29), http://www.youtube.com/watch?v=_rE3r262CQk

[Source: www.flickr.com/photos/oliwilken/ and stjohnscathedral.org.hk]

A historical church building in HK 香港一座歷史悠久的教堂建築

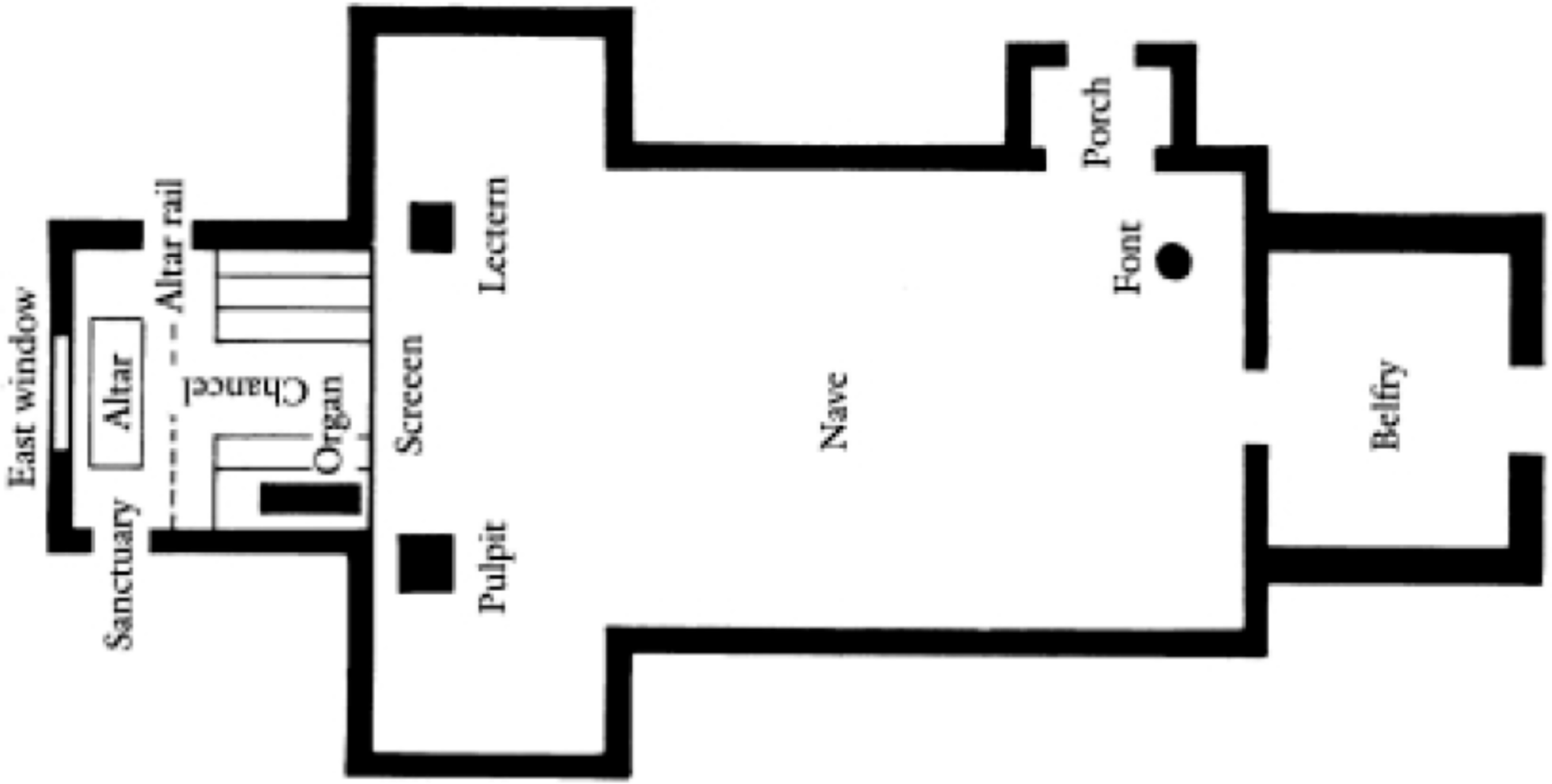
[Source: http://commons.wikimedia.org/wiki/File:HK_St_John%27s_Cathedral_Interior.jpg]

A historical church building in HK 香港一座歷史悠久的教堂建築



[Source: http://www.stjohnscathedral.org.hk/history.html]

Typical layout of a cathedral church 大教堂的典型佈局



Six major components:

(a) Altar 祭台

(b) Ambo (now called Lectern) 讀經台

(c) Seat of the priest 主祭座位

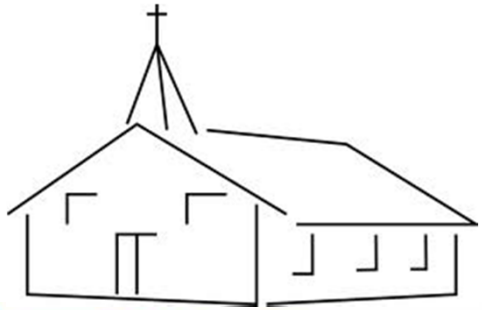
(d) Laity seating area 信友位置

(e) Baptismal font 洗禮池

(f) Other facilities and decorations 其他設備和裝飾

[Image Source: Instant Art for Teaching Christianity]

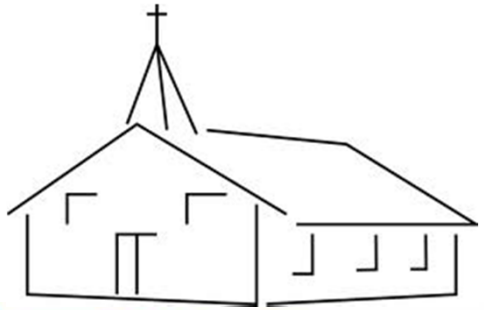
Church Buildings in HK
香港的教堂建築



- Modern church buildings 現代的教堂建築*
  - Purposely built; converted from other uses; renovated old churches
  - Multi-functional, fan-shaped interior
  - Adequate amenities (e.g. air conditioning, toilets, bride rooms) and a good sound system
- Church furnishing and decoration 教堂的裝飾
  - Need to adhere to liturgical spirit and norms 要堅持守教區禮儀的精神和規範

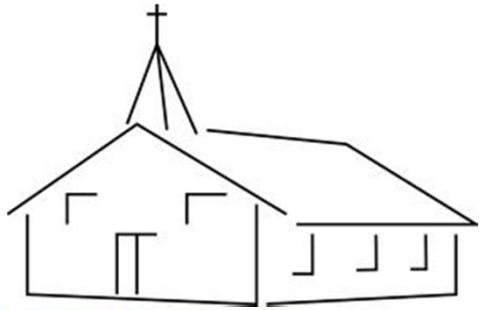
* Example (video, 5:03): Hong Kong Baptist Church – intro, http://www.youtube.com/watch?v=7YWcyH7K4TE

Church Buildings in HK
香港的教堂建築



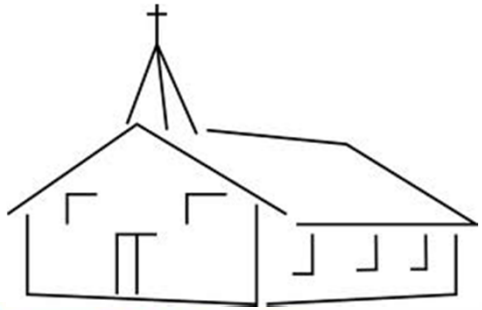
- Patterns of energy use 能源使用的模式
  - Very different from commercial/residential sectors
  - Peak on weekends and lessen during weekdays with occasional spikes for special meetings or functions
  - The large worship hall/space requires significant energy to cool and/or light up
  - Multiple users with different behaviour

Church Buildings in HK
香港的教堂建築



- Historical church buildings 歷史教堂建築
  - A declared monument (St. John's Cathedral) and 35 church buildings graded historic monuments
    法定古蹟(中環聖約翰座堂)和35項歷史古蹟
  - Important to understand the heritage values and observe the conservation principles 重要的是要了解文物價值和守紀保護原則

Church Buildings in HK
香港的教堂建築



- Case studies 案例研究
  - Site visits and energy assessments in 2011-2012
  - Include 3 historical church buildings and 3 others
  - Also examine HK energy audit guidelines
  - Findings: main energy conservation potential is on design, operation and management of lighting and air conditioning systems

Church Buildings Studied 教堂建築研究

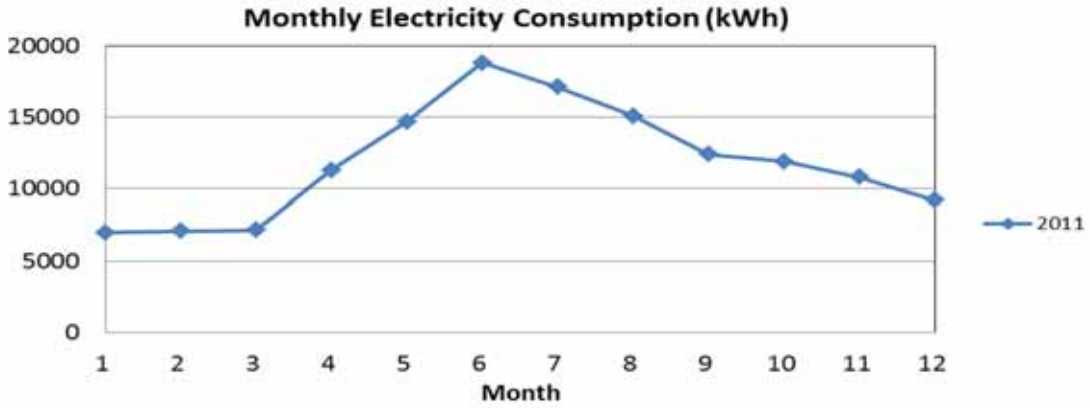
Table 2.3 Historical church buildings studied in late 2011 to early 2012

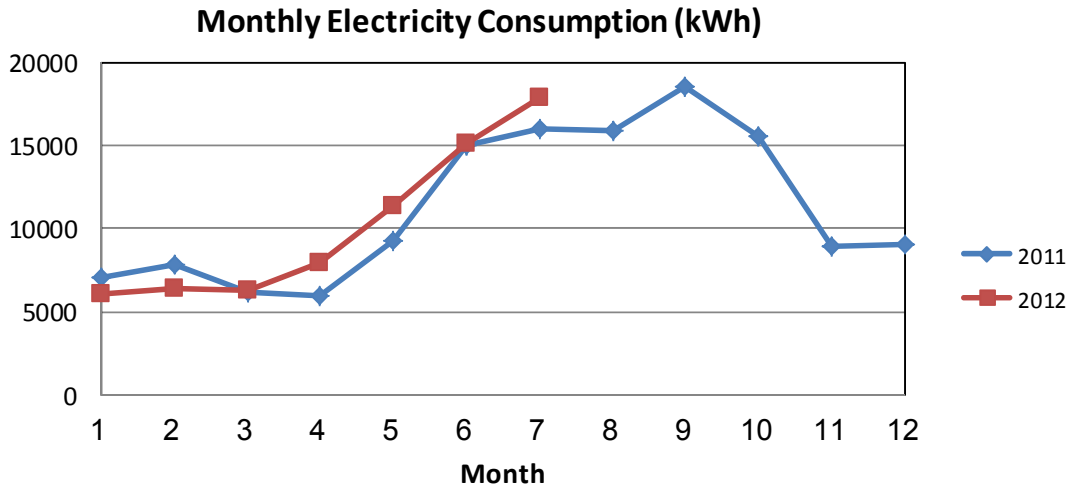
Name	Chinese Rhenish Church	Kau Yan Church	St. Anthony Church
Location	Bonham Road	High Street	Pokfulam Road
Year Built	1941	1932	1953
Partner school	Rhenish Mission School	Kau Yan School	St. Anthony's School
Total floor area	990 m^2	1,053 m^2	585 m^2 (hall only)
Historic grade	Proposed Grade 3	Grade 1	Grade 2
	禮賢會香港堂	救恩堂	聖安多尼堂

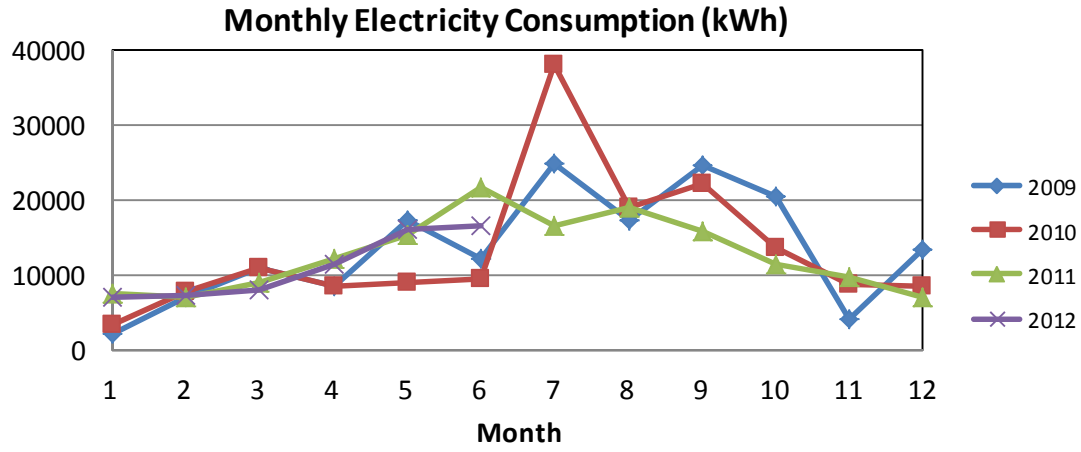
Table 2.4 Church buildings studied in the summer of 2012

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
	聖母玫瑰堂	聖猶達堂	聖斯德望堂

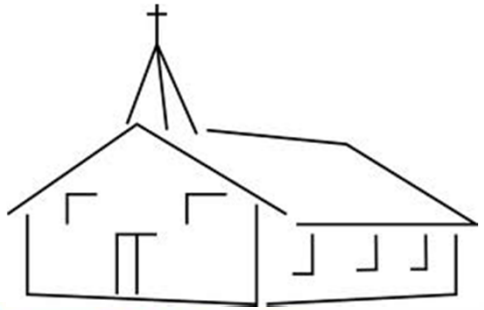
Electricity consumption of church buildings 教堂建築的耗電量







Church Buildings in HK
香港的教堂建築



- Limitations in case studies: 案例研究的限制
  - Not easy to collect and analyse the energy data
    - Records not maintained well
    - Electricity bills mix with other areas e.g. schools
  - Breakdown of the energy data is not feasible due to lack of information
    - No sub-metering for lighting and air conditioning
  - Weekend worship gatherings are regular, but special functions will vary (no records to trace)

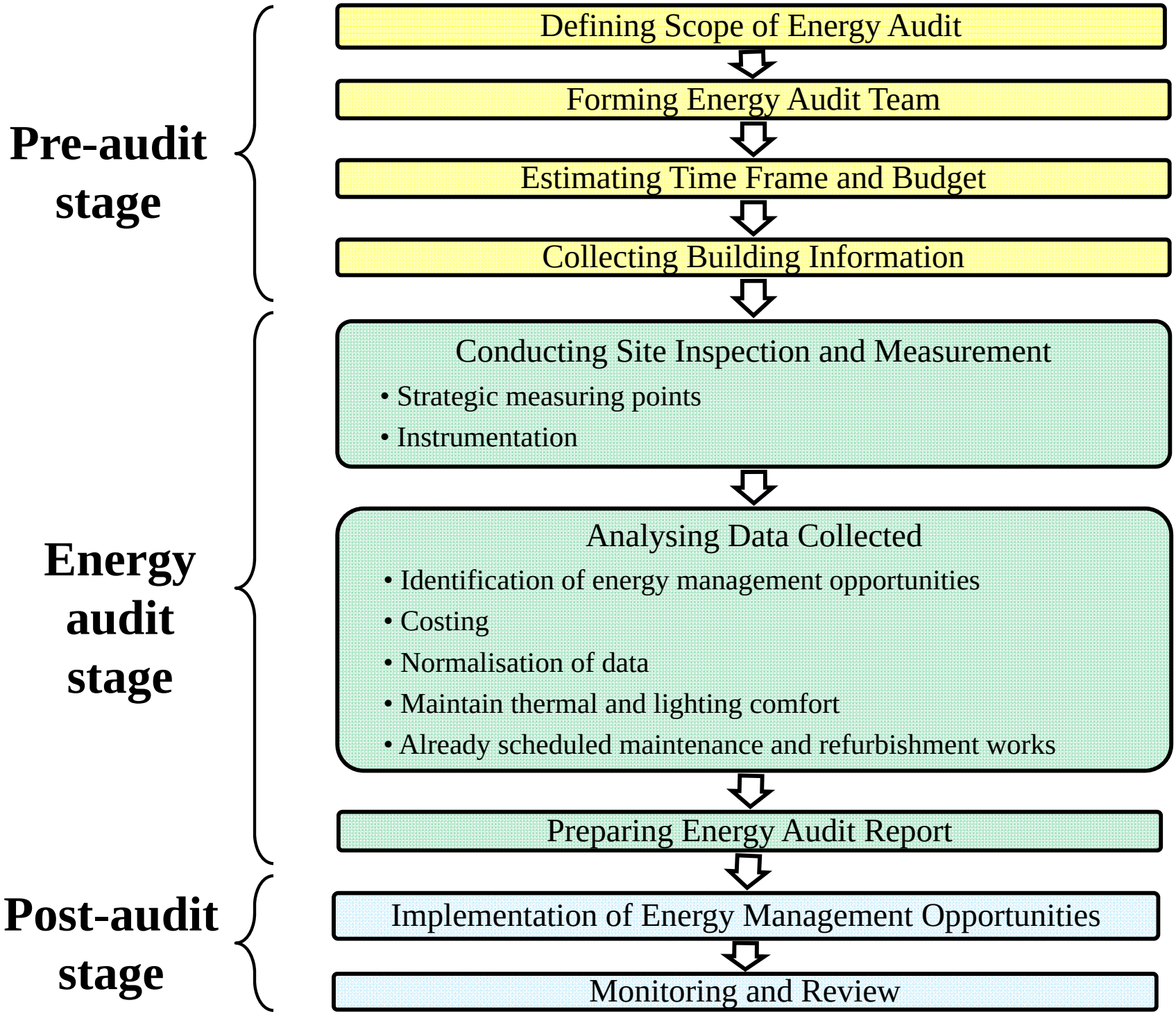
Energy Audit Process
能源審核的過程

- Definition of Energy Audit 能源審核的定義
  - “Examination of an energy consuming equipment/system to ensure that energy is being used efficiently” (EMSD, 2007) 是指對耗能設備和系統進行檢查，以確保高效率地利用能源
    - Identify energy management opportunities (EMO)
    - Provides useful information for the building owner to decide on and implement the energy saving measures

Energy Audit Process
能源審核的過程

- The term "*energy audit*" 術語: "能源審核"
  - It is perceived as carrying the negative connotations (an involuntary investigation of finances, where the intended goal is to uncover mistakes and assess monetary penalty) 負面含義
- Better to avoid such negative connotations
  - To gain better acceptance by the building managers and operators
  - The term "*energy assessment*" is preferable
    " 能源評估 " 是較好的

Procedure of energy audit 能源審核程序



Energy Audit Process
能源審核的過程

- Useful toolkit in HK: 在香港的有用工具
  - EMSD energy audit guidelines 能源審核指引
  - Energy Audit Code (EAC) 能源審核守則
  - Building Energy Code (BEC) 建築能源效益守則
- References from other countries: 從其他國家的參考書
  - ASHRAE (2011): procedure for energy audit
  - CIBSE (2012): energy efficiency in buildings
  - Other guides and reference books

Energy audit process 能源審核的過程

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

Energy Audit Process
能源審核的過程

- Levels of effort of energy audit (ASHRAE, 2011) 能源審核的努力水平
  - 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)

Energy Audit Process
能源審核的過程

- Will need assistance and cooperation from the end-users and building staff 需要最終用戶和建築物人員的援助和合作
- 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 如果教堂是位於商業、住宅和校舍內，有必要考慮是否可以適用於整個建築群的能源審核

Typical structure of an energy audit report 能源審核報告的典型結構

Executive Summary

- Overview of the audit, EMOs identified
- Recommended actions, briefing on implementation plan

Introduction and Building Information

- Objectives, energy audit scope, audit team
- Building characteristics (type, floor areas, operation)

Description of the Equipment/Systems Audited

- System types, capacity ratings, zoning, operation hours etc.

Energy Data and Survey Findings

- Historical energy consumption of the building
- System performance evaluation, O&M practices

Energy Management Opportunities

- Identification & evaluation of potential EMOs
- List of recommended EMOs and implementation plan

Conclusions and Recommendations

Energy Mgt. Opportunities
能源管理機會

- 3 categories of EMOs: 三類能源管理機會
  - ***Category I (no cost)***: 第 I 類（無成本）
    - Housekeeping measures which are improvements with practically no cost investment and no disruption to building operation
  - ***Category II (low cost)***: 第 II 類（低成本）
    - Changes in operation measures with relatively low cost investment
  - ***Category III (high cost)***: 第 III 類（高成本）
    - Relatively higher capital cost investment to attain efficient use of energy

Energy Mgt. Opportunities
能源管理機會

- Churches: 3 simple factors for energy waste
  教堂建築: 3個簡單的能源浪費的因素：
  - Inefficient operation 低效運作
  - Inefficient equipment 低效率的設備
  - Building energy inefficiency 建築不節能

Energy Mgt. Opportunities
能源管理機會

- Two typical issues in churches:
  - Lack of knowledge about what can and cannot be turned off
  - Lack of dedicated person to ensure systems are regularly checked
- 在教堂的兩個典型問題：
  - 缺乏了解什麼可以和什麼不能關閉
  - 缺乏專人定期檢查，以確保系統效率

Energy Mgt. Opportunities
能源管理機會

- EMOs of lighting systems 照明系統的能源管理措施
  - Daylighting design 採光設計
  - Sanctuary lighting 聖殿的照明
  - Lighting controls 照明控制
  - Scheduling and zoning 調度和分區
- Lighting retrofit 照明系統改造
  - Such as changing to compact fluorescent lamps (CFLs) or light emitting diode (LED) sources

Daylighting design for church buildings 教堂建築的自然採光設計

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

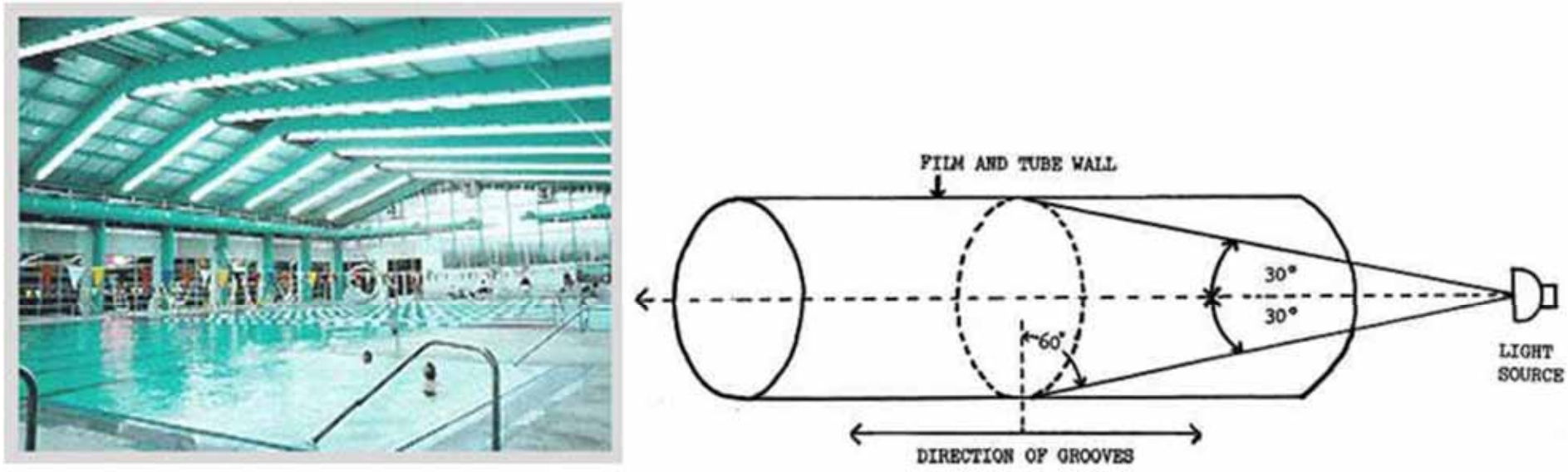


Figure 4.2 Light pipe for admitting natural daylight into buildings (Source: 3M.com)

Sanctuary Lighting 聖殿照明

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)

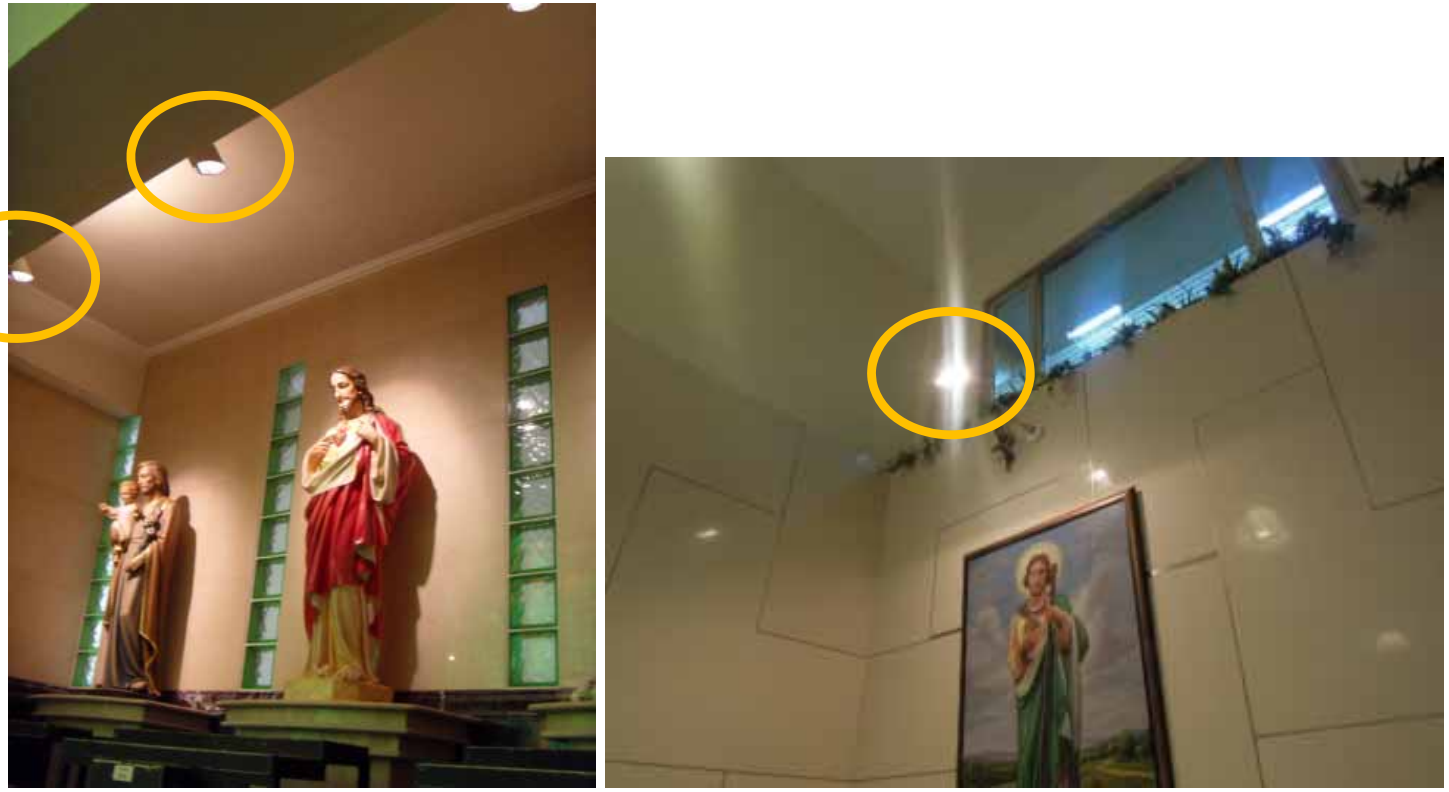


Figure 4.4 Sanctuary lighting for statues and images

Energy Mgt. Opportunities
能源管理機會

- Common lighting controls: 一般照明控制
  - Bi-level switching 雙級開關
  - Dimmers 調光器
  - Occupancy sensors 人員感應器
  - Daylight sensors (photocells)日光傳感器（光電）
- Scheduling and zoning 調度和分區
  - Arrange a smaller space/zone/room for serving small services having less number of people
  - Schedule cooling and lighting zones

Scheduling and zoning 調度和分區

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

Energy Mgt. Opportunities
能源管理機會

- Air conditioning systems 空調系統
  - Used in the churches in HK since 1960s
  - Constitutes most of the electricity consumption
  - EMO: use energy-efficient air-conditioners and smart use of air-conditioners
- Church renovation projects 教堂改造項目
  - Need to upgrade the rather outdated air conditioning and building services systems

Air conditioning for churches 教堂空調

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

Air conditioning for churches 教堂空調

Figure 4.7 Examples of air conditioning equipment for a church building

Energy Mgt. Opportunities
能源管理機會

- Difficulties of church air conditioning design
  教堂的空調設計的難點
  - Large spaces and overhead
  - Fluctuating usage patterns
  - Window design with large swaths of stained glass
  - Historic nature (no unsightly ductwork/equipment)
  - Pitched slate roof (not possible to put equipment)
  - Long window wells (hard to put condenser units)

Energy Mgt. Opportunities
能源管理機會

- Air conditioning: energy management factors
  空調：能源管理因素
  - Maintenance is a key concern 維護是關鍵問題
    - Seasonal tune-ups and checking, inspection for leakage or damaged insulation, proper individual temperature control, optimum start/stop of equipment
  - Select new advanced efficient systems, e.g.
    - High-efficiency variable refrigerant flow (VRF)
    - Multi-split and heat pump systems
    - Demand-controlled ventilation (DCV)

Energy Mgt. Opportunities
能源管理機會

- Air conditioning: energy management factors
  空調：能源管理因素
  - Properly size the equipment
  - Economizers (or free cooling)
  - Energy recovery ventilation systems
  - Variable speed drive (VSD) in fans and pumps
  - Thermal energy storage systems
  - Consider natural or mixed-mode ventilation

Energy Mgt. Opportunities
能源管理機會

- Electrical equipment and appliances 電氣設備和電器
  - e.g. room air conditioners, refrigerators, computers, LCD projectors, printers, photocopiers 例如冷氣機、雪櫃、電腦，液晶投影儀，打印機，影印機
  - Energy efficiency labels in HK 香港的能源標籤
    - Grading type and recognition type 級別式和確認式
  - Equipment procurement and operation 設備採購及操作

Energy efficiency labels in HK 香港的能源效率標籤

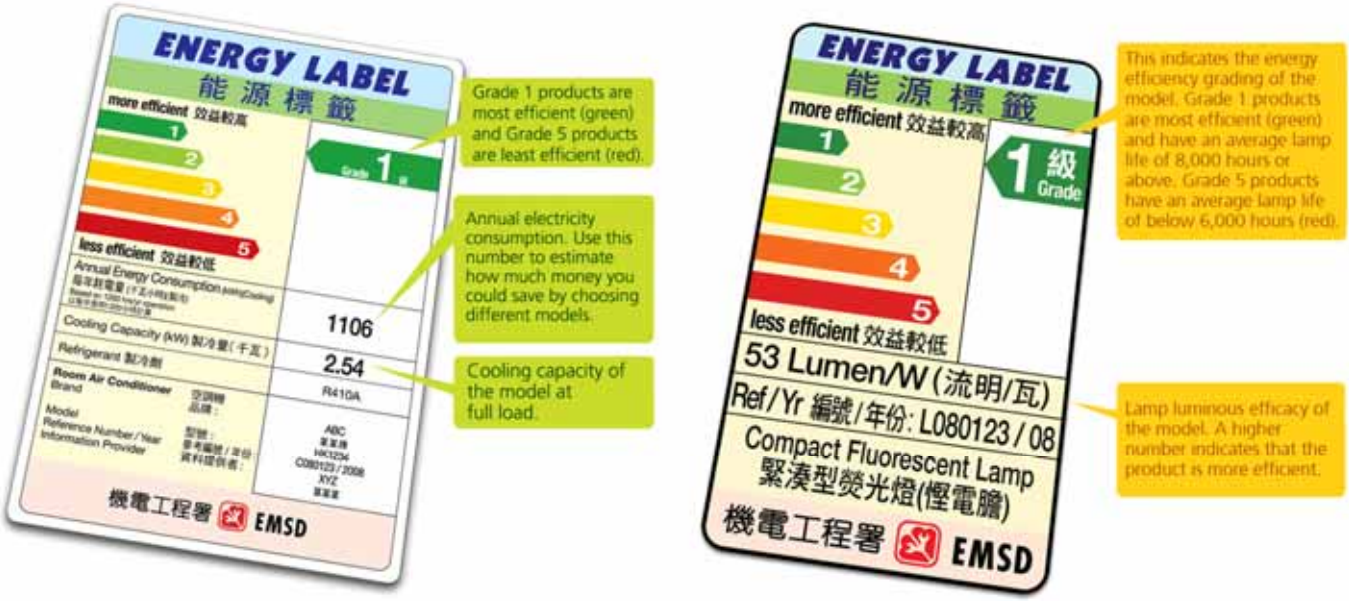


Figure 4.8 Examples of mandatory energy efficiency labels in Hong Kong

Figure 4.9 Examples of voluntary energy efficiency labels in Hong Kong

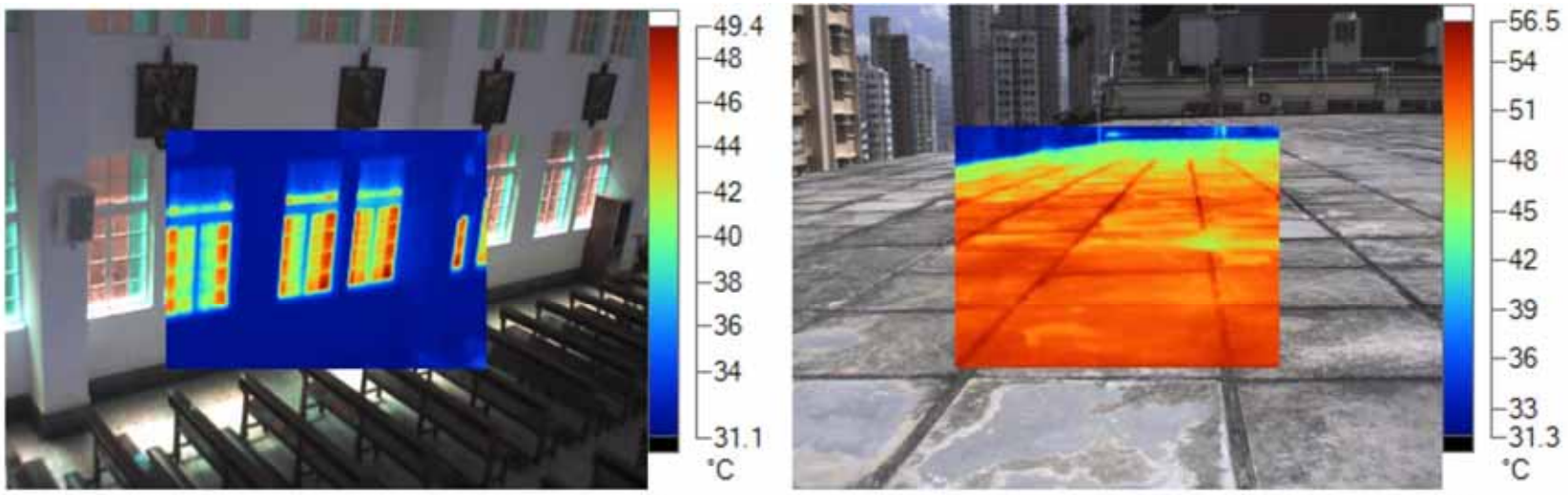
[Source: www.energylabel.emsd.gov.hk]

Energy Mgt. Opportunities
能源管理機會

- Building envelope (windows, walls and roofs)
  圍護結構（窗，牆壁和屋頂）
  - Minimise heat transfer to reduced space cooling
  - Windows:
    - High-performance low emissivity (low-e) insulated glass and thermally improved frames
    - Sun shading devices and solar control design
    - Add an extra layer of windows
    - Solar window film

Building envelope 建築圍護結構

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

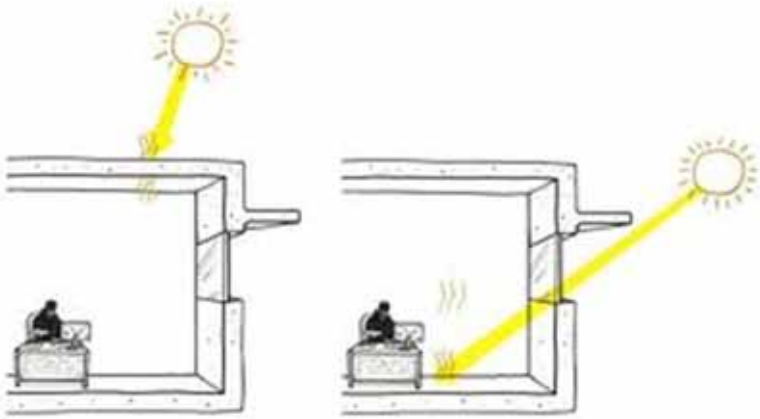


(a) External windows and walls *(b) Roof surface*

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

Energy Mgt. Opportunities
能源管理機會

- Building envelope: Walls and roofs 圍護結構（牆壁和屋頂）
  - Wall/roof thermal insulation
  - Sealing cracks and leaks
  - Use of thermal mass



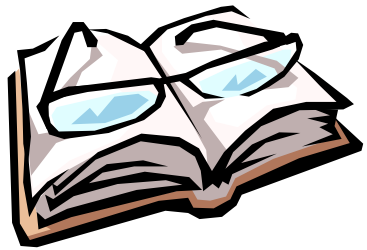
- Roof spaces 屋頂空間
  - Potential for solar systems (photovoltaic or solar thermal hot water) and green roofs 太陽能系統(光伏或太陽能光熱熱水)和屋頂綠化的潛力

Potential roof spaces for PV, solar hot water and green roofs
屋頂空間可發展光伏發電、太陽能熱水和屋頂綠化

Figure 4.12 Roof spaces in the church buildings in Hong Kong

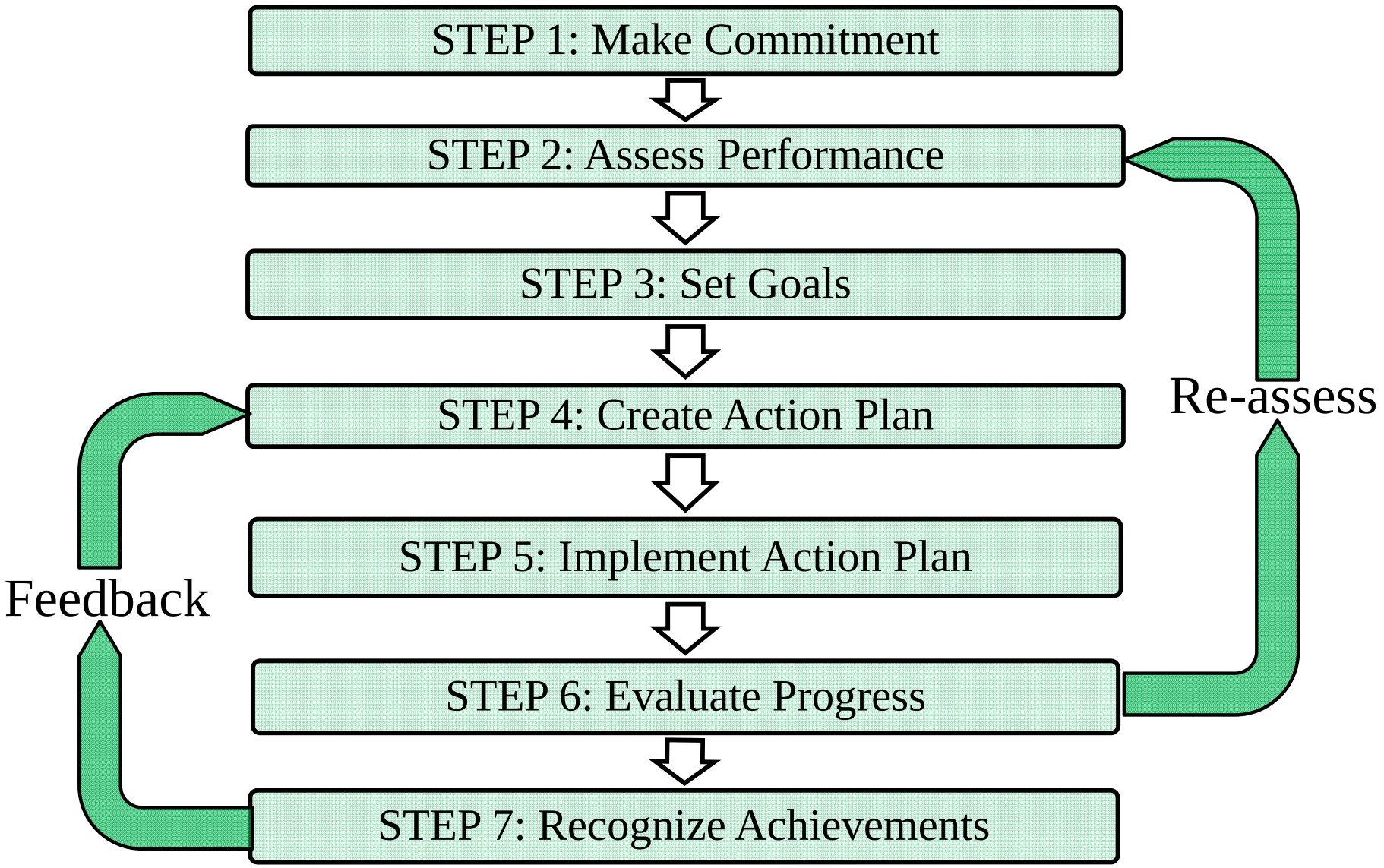
[Source: http://www.baps.co.nz]

Major Considerations
主要考慮因素

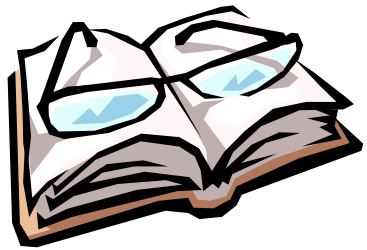


- Both technology and people must be focused in building energy management and assessment 建築節能管理和評估都必須集中在技術和人員上
  - For churches: the PEOPLE factor is important
  - A process of continuous improvement
  - PDCA circle (Plan-Do-Check-Act) 計劃 - 執行 - 檢查 - 行動

Important steps for energy management 能源管理的重要步驟



Major Considerations
主要考慮因素



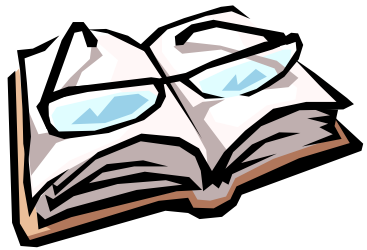
- Commitment to energy efficiency 對節能承諾
  - Organisational commitment 組織承諾
  - Technological commitment 技術承諾
  - Commitment to behavioural change行為改變承諾
- Energy management and conservation policy 能源管理和節約政策
  - Broadly communicated to volunteers and contractors; Should agree a champion to lead the work to manage energy and emissions

Commitment to energy efficiency 對能源效率的承諾

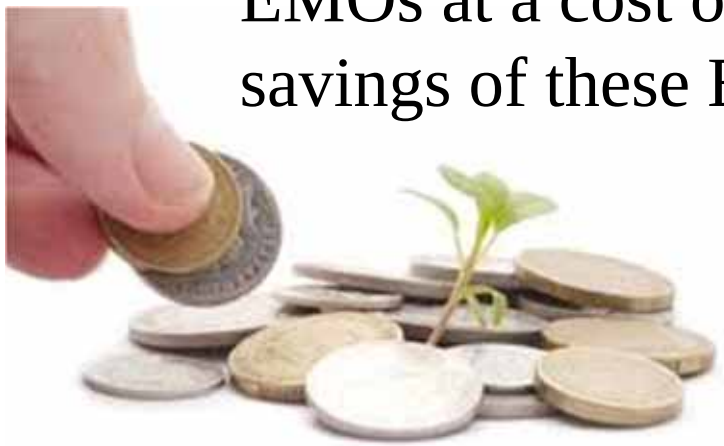
Table 5.1 Commitment to energy efficiency for religious buildings [adapted from Climate Change Centre (2006))

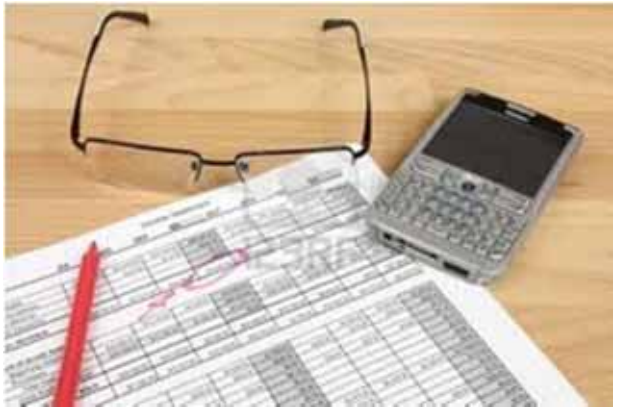
Organisational Commitment	• The more people who commit to action within a place of worship, the stronger the project. Having a project champion(s) is essential. • Concerted action within an organi sation will lead to more resources, ideas, and creative ways to move forward on energy efficiency. • Time 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 manag ement 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.

Major Considerations
主要考慮因素

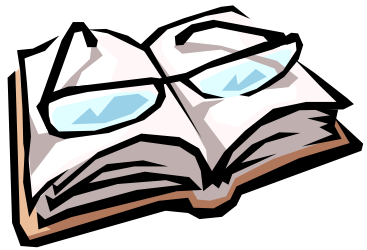


- Finding and raising funds 查找和籌集資金
  - Assess the savings potential 評估節約潛力
  - Financial analysis 財務分析
  - Performance contracting 績效合同
    - The service provider will design and implement the EMOs at a cost of a certain percentage of the total savings of these EMOs





Major Considerations
主要考慮因素



- Environmentally friendly church 環保教會
  - Energy is the first step to green
  - Other green actions to consider:
    - Reduction and recycling of waste, using locally-produced and fairly traded foods, reducing car travel, conserving water, installing solar panels and applying green roofs

Environmentally friendly church 環保教會

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

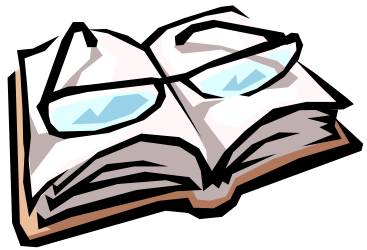
Water efficiency
- Low-flow toilets and low-flush urinals
- Flow restrictors on taps
- Rain water harvesting
- Grey water recycling

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 (volati le organic compounds) materials
- Promote natural daylight

Caritas - Ming Fai Camp
明愛 - 長洲明暉營

Major Considerations
主要考慮因素



- Education & spiritual study 教育和精神文明
  - Establish energy education and training 建立能源教育和培訓
  - Examples:
    - Engage the youth group in a church energy audit
    - A night of spiritual study on energy and environment
    - Forums and brainstorming sessions
  - Energy assessment and improvements as educational experience for adults and children

Conclusions 結論

- Potential of energy conservation 節能潛力
  - Improve the current 1,250 churches in HK
  - Promote to the churches in other cities/countries
  - Apply to buildings of other religious groups, e.g. Buddhism, Taoism, Confucianism, Islam, Hinduism, Sikhism and Judaism
    - HK has about 600 temples, shrines and monasteries

Conclusions 結論

- Major recommendations: 主要建議
  - Each church has an energy management team
  - Church energy accounting/information systems
  - A high-level church energy conservation policy
  - Energy efficiency in the procurement policy
  - Energy audit forms and guidelines for churches
  - Energy management in church renovation projects

THANK YOU 謝謝

祝聖誕快樂