UNEP

Climate Friendly Buildings and Offices

A Practical Guide

Sustainable United Nations

ERM

United Nations Environment Programme

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Climate Friendly Buildings & Offices

A Practical Guide

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Acknowledgement

UNEP gratefully acknowledges the time and effort spent by those involved in producing and commenting on this *Climate-Friendly Buildings and Offices: A Practical Guide*.

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Invaluable inputs were also provided by members of the Inter-Agency Network of Facilities Managers (INFM) and experts. In particular, UNEP wishes to extend our special thanks to Adam Hinge (Sustainable Energy Partnership), Mary Beth Kelly (International Monetary Fund), Rom Kieffer (UN Office at Vienna), Alireza Ghaemi and Siamak Sekhavat (UN Industrial Development Organization), Heather Kilner (UN International Criminal Tribunal for the former Yugoslavia), Priyanka Kochhar (The Energy and Resources Institute, India), and Steffen Wissing (ALECTIA) for their technical advice and review.

Preparation and publication of the Guide was made possible by financial support from the Norwegian Government, which UNEP gratefully acknowledges.

Foreword

The United Nations Secretary-General Ban Ki-moon has referred to climate change as the “defining challenge of our time”. On 5 June 2007, he publicly called on UN agencies, funds and programmes to lead by example and become climate neutral and more sustainable.

In response to this call, the United Nations Chief Executives Board approved the Climate Neutral Strategy in October 2007, which commits the UN system to measure, reduce and consider the implications for offsetting greenhouse gas (GHG) emissions from its operations.

The first assessment of UN system’s carbon footprint published in December 2009, revealed that about 40 per cent of emissions come from operating the buildings occupied by the UN. With offices in more than 530 locations globally, this provides a huge opportunity to improve the energy efficiency of our buildings, while providing practical examples of the benefits of more sustainable buildings to host nations around the world.

The *Climate-Friendly Buildings and Offices: A Practical Guide* has been prepared to this end. It provides robust, hands-on advice to facility managers to reduce energy consumption and improve the efficiency of their buildings. Though primarily aimed at assisting UN facility and property managers, this Guide is also applicable to other building mangers who are looking to reduce office-related energy and GHG emissions.

The UN family has embarked on a journey to reduce our carbon footprint. We now know the areas in which we need to focus our efforts. UN buildings and facilities is clearly one of them.

I hope the publication of the *Climate Friendly Buildings and Offices: A Practical Guide* will assist the UN’s facility managers to lead by example and help make energy efficient and low-GHG emission buildings the norm in the UN system.

Sylvie Lemmet

Director, Division of Technology, Industry and Economics
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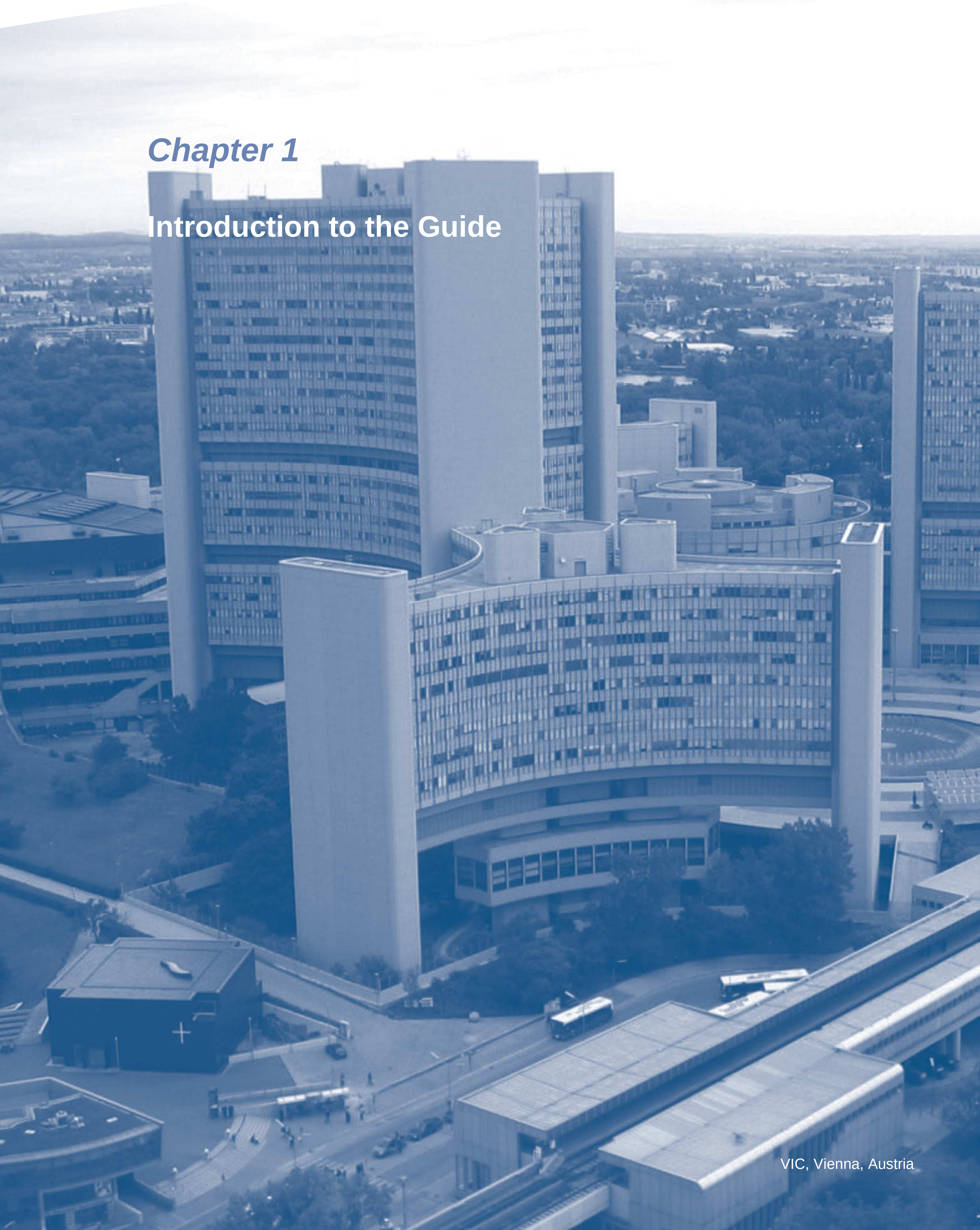
Chapter 1

Introduction to the Guide



VIC, Vienna, Austria

1. Introduction to the Guide

1.1 UN Context

The United Nations Chief Executive Board (CEB) adopted in October 2007 a Climate Neutral Strategy for the United Nations (UN). This strategy commits all UN agencies, funds and programs to calculate their greenhouse gas (GHG) emissions, to reduce their emissions of GHG to the extent possible, and to prepare required data and economic analysis for purchasing offsets for remaining emissions.

In order to support UN agencies, funds, programmes and partner organisations (collectively referred to hereinafter as 'organisations') to reduce their GHG emissions, the United Nations Environment Programme (UNEP) established in early 2008 the Sustainable United Nations (SUN) Facility. SUN assists organisations to identify opportunities for direct and indirect emission reductions from their operations, including buildings and facilities, travel, procurement and through communication and staff engagement. SUN is currently developing a number of tools and resources to further assist organisations in their efforts.

UN Headquarters, New York, USA

1.2 Objective of This Guide

One of these tools will be this guide for facility and office managers on how to reduce GHG emissions in existing offices, *Climate Friendly Buildings and Offices: A Practical Guide* (referred to hereinafter as "the Guide"). The UN currently maintains offices in more than 530 locations worldwide. The majority of these are leased or rented and are often managed and maintained by the UN organisation. However, as ownership belongs to other parties, the opportunities for major renovations and investments are typically limited. The opportunities for improvements are in many cases further limited if the office is occupying only parts of the building.

The stated aim of this Guide is to assist UN organisation offices in becoming 'climate friendly', meaning that offices will generate lower GHG emissions during their operation than would be standard practice.

All the measures and recommendations put forward by this Guide are focused on the end goal in mind, the reduction of GHG emissions from offices. Acknowledging that in most instances the office space is leased, the Guide therefore provides practical advice on what can be done to reduce emissions under these circumstances, and how these opportunities can be identified and assessed. It is noted that the wider topic of sustainable buildings and offices covers a broader remit than that covered by this Guide, such as issues like indoor air quality, waste management, water management and material procurement

and use. This Guide is intentionally focused on GHG emission reductions from existing offices, and therefore by association energy efficiency and conservation.

Throughout the Guide, reference is made to UN offices, where 'offices' relates to the range of office space scenarios that the UN organisations occupy, ranging from small rented office spaces, offices over several floors through to entire buildings.

The Guide presents direct and indirect emission reduction opportunities and focuses on improvements that can be made to existing systems and management approaches, including minor to moderate upgrades and replacement. This guide will aid the UN organisations in overseeing their offices towards becoming more climate friendly, while providing staff with an easy to use practical guide book on recommendations for their office. Though aimed at facility and property managers and maintenance staff, this Guide is equally applicable to any managers of UN organisation offices or departments that are looking to save office related energy and reduce GHG emissions. The Guide also provides three case studies where implementation of the Guide and GHG reduction measures are illustrated (see **Section 6**).

1.3 How to Use The Guide

The Guide has been structured as follows:

- **Chapter 1** – Provides an overview of the Guide;
- **Chapter 2** – Provides the context for the Guide in terms of the importance of the role buildings have to play in climate change abatement;
- **Chapter 3** – Provides a step-by-step approach to preparing and getting started by assessing baseline performance and benchmarking;

- Chapter 4 – Provides guidance on taking action for identifying and assessing GHG reduction opportunities (this section in turn links to the main listing of measures presented in Annex A);
- Chapter 5 – Provides a discussion of the implementation steps once GHG reduction opportunities have been identified;
- Chapter 6 – Provides three case studies from UN agencies and partner organisations of how the Guide and GHG reductions have been implemented; and
- Chapter 7 – Provides a section on further help and support for UN organisations.

The supporting Appendices are:

- Annex A – Contains the full set of identified GHG reduction measures as follows:
    - A.1 Energy Supply and Distribution (ESD)
    - A.2 Operations and Behaviour (OPS)
    - A.3 Lighting (LIG)
    - A.4 Heating, Ventilation, Air Conditioning and Refrigeration (HVAC)
    - A.5 Building Envelope (ENV)
    - A.6 Office Equipment (OFF)
    - A.7 GHG Compounds and Refrigerants (REF)
- Annex B – Glossary of terms; and
- Annex C – Acronyms.

Figure 1.1 provides a flowchart for using this Guide, identifying a recommended minimum pathway for use and implementation, as well as additional optional approaches which provide a more considered and comprehensive framework for managing GHG emissions.

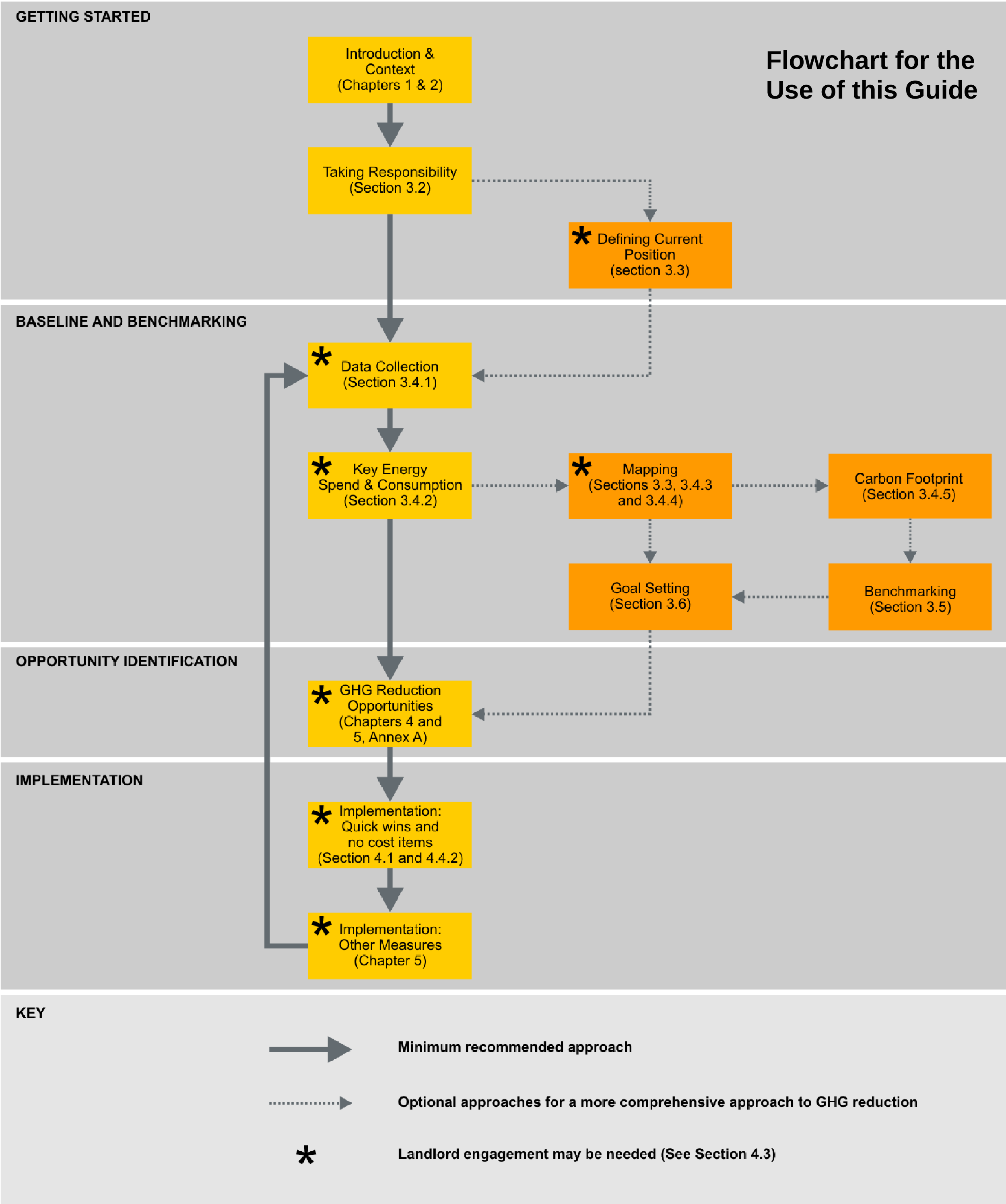


Figure 1.1 Flowchart for Using This Guide

Chapter 2

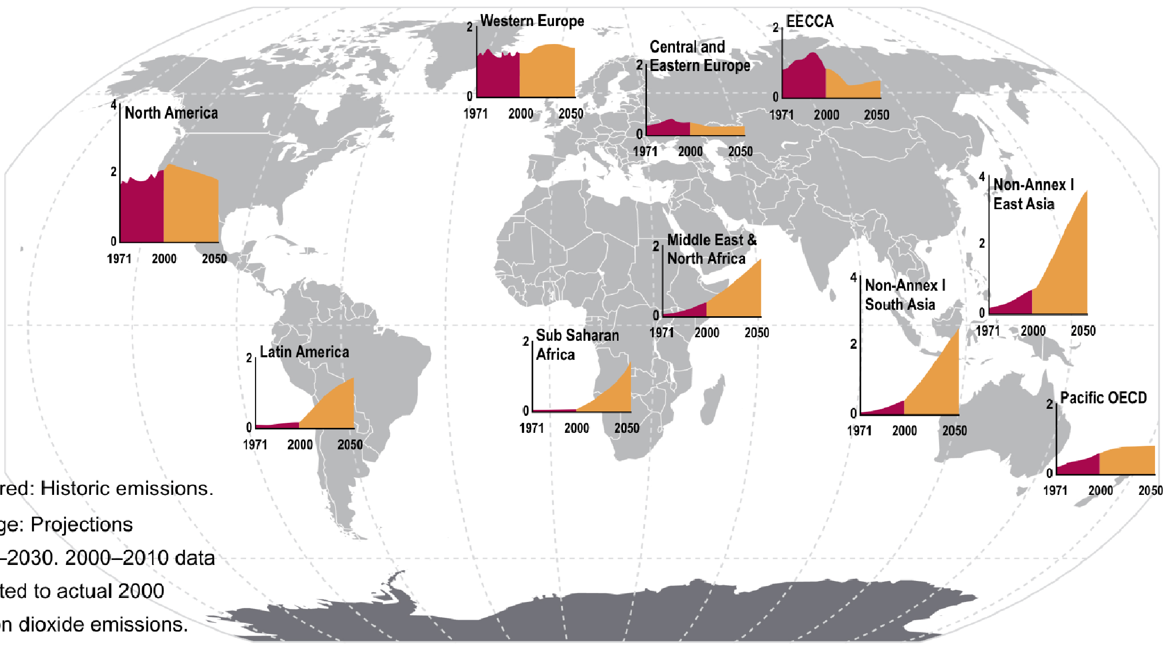
Context

Palais des Nations, Geneva, Switzerland

2.1 Climate Change and Buildings

Buildings are responsible for more than 40% of global energy use and approximately one third of global GHG emissions, both in developed and developing countries.

Buildings are a major energy consumer and source of GHG emissions. This energy use and the associated GHG emissions are growing rapidly and unsustainably. According to the Fourth Assessment Report of the Inter-Governmental Panel on Climate Change (IPCC, see **www.ipcc.ch** for details about the IPCC and their Fourth Assessment Report), building-related GHG emissions were estimated at 8.16 million metric tons CO_2 equivalent (CO_2-e) in 2004. Under the IPCC's high growth scenario, this value could almost double by 2030 to reach 15.6 billion metric tons CO_2-e, as illustrated in **Figure 2.1**.



Note:
Dark red: Historic emissions.
Orange: Projections 2001–2030. 2000–2010 data adjusted to actual 2000 carbon dioxide emissions.

Figure 2.1: CO_2 emissions from buildings (in GtCO2) including through the use of electricity – IPCC high growth scenario

(Source: Adapted from Figure 5.2, p392 of Contribution of Working Group III to the Fourth Assessment Report of the IPCC, 2007. B.Metz, O.R.Davidson, P.R.Bosch, R.Dave, L.A.Meyers (eds), Cambridge University Press)

Due to the magnitude of its impacts, the building sector can significantly contribute to sustainable development by delivering significant GHG emission reductions, energy and resource efficiency and cost savings, whilst at the same time generating other benefits such as the creation of jobs. The IPCC's Fourth Assessment Report identifies that the GHG emissions (through energy consumption) in both new and existing buildings can be cut by an estimated 30-50% without significant increases in investment costs. Further details regarding the contribution and opportunity of the building sector for GHG reductions can be accessed through UNEP's Sustainable Buildings and Climate Initiative (SBCI) at **www.unep.org/sbci**.

2.2 Office Energy Use and GHG Emissions

Throughout this Guide, GHG emission reductions and energy management are inter-linked. Most GHG emissions are generated from the use of energy, therefore by stressing energy management and savings opportunities, by default GHG reductions are inferred.

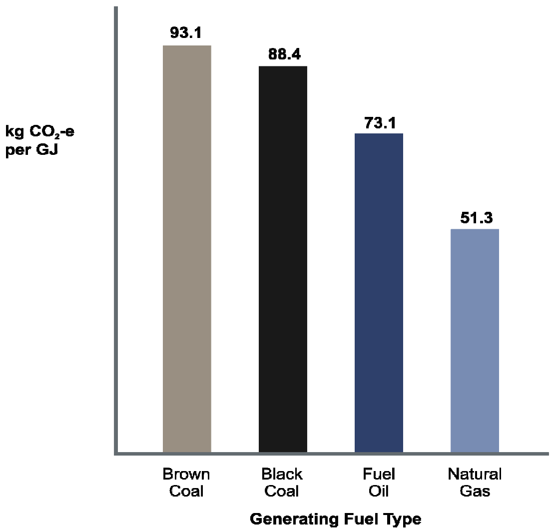


Figure 2.2 CO_2e emissions from electricity generation in Australia for different fuels

(Source: Australian Government, 2008, National Greenhouse and Energy Reporting (Measurement) Determination)

This Guide is focused on the operational use of offices and buildings. The pattern and level of energy consumption, and hence GHG emissions, in offices depends upon a number of factors, many of which interact with each other. Most importantly, the level of GHG emissions from offices depends upon the source of the energy they use. In most countries, the energy used in buildings is derived from external electricity generation, which in most cases is derived principally from fossil fuels, but this is complemented in some countries by nuclear energy and/or renewable energy. **Figure 2.2** illustrates the differing GHG intensity of fossil fuels based upon their CO_2e emissions per unit of electricity produced. Renewables and nuclear do not generate direct GHG emissions and are therefore not shown in Figure 2.2, although they do contribute indirect GHG emissions.

The method used by the UN to assess the GHG impacts of buildings is the Greenhouse Gas Protocol (GHG Protocol), a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The GHG Protocol (see **www.ghgprotocol.org**) is the most widely used international accounting tool to understand, quantify and manage GHG emissions. It serves as the foundation for most GHG standards and programmes used today.

The GHG Protocol was designed with the following objectives in mind:

- To assist organisations in preparing a GHG inventory that represents a true and fair account of their emissions, through the use of standardised approaches and principles;
- To simplify and reduce the costs of compiling a GHG inventory;
- To provide organisations with information that can be used to build an effective strategy to manage and reduce GHG emissions; and
- To increase consistency and transparency in GHG accounting and reporting.

The GHG Protocol defines three “scopes” (scopes 1, 2 and 3) in order to help delineate direct and indirect emission sources, improve transparency and avoid double counting between organisations. **Figure 2.3** summarises the GHG emission scopes.

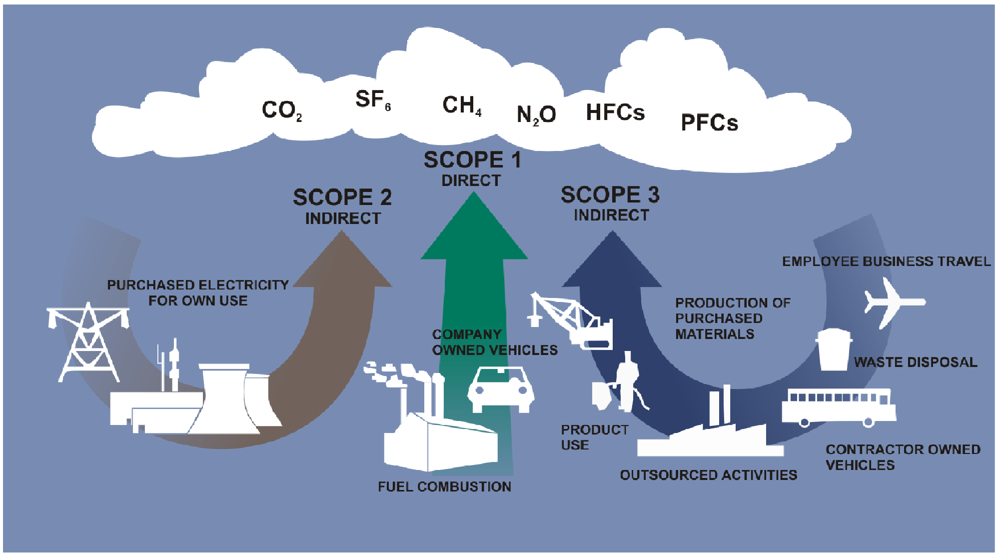


Figure 2.3: Depiction of Greenhouse Gas Protocol Emissions 'Scopes'

(Source: GHG Protocol, Corporate Accounting and Reporting Standard (Revised Edition), adopted from NZBCSD 2002)

Scope 1 refers to direct GHG emissions which occur from sources that are owned or controlled by the organisation. For offices, scope 1 emissions might arise from primary energy generation, such as boilers and generators, as well as from the release and leakage of refrigerants from office equipment. Scope 2 refers to indirect GHG emissions from the generation of purchased electricity consumed by the organisation. Scope 3 is an optional reporting category that refers to all other indirect emissions. Scope 3 emissions are a consequence of the activities of the organisation, but occur from sources not owned or controlled by the organisation, such as waste disposal and commercial airline business travel.

The focus of this Guide for GHG reductions are Scope 1 and 2 GHG emissions from offices.

In addition to the source of energy used by offices, other important factors in determining energy consumption and GHG emissions include:

- ***Office activities and usage***: The activities undertaken in an office may be simple administrative activities relying on computers and other office equipment, but equally could include energy intensive computer servers and data centres. In addition, occupancy patterns, whether more traditional 9 to 5 working hours through to 24 hour operations also affect energy profiles.

- ***Building, age, design and materials***: The design and materials used in construction of the building, partly influenced by a building's age, also have a significant influence on energy demands. Influencing aspects include insulation, window types, passive designs, efficiency of installed lighting, appliances, ventilation, cooling and space heating systems, water heating, material selection and back-up power supplies. For example, global trends in the use of extensive glazing in office buildings has led to a rise in demand for cooling systems and hence increased energy demand.

- ***Climate and location***: Climatic conditions and the type of environment in which an office is located impact the energy needs of an office, such as heating, cooling and lighting requirements. For example, for every 1°C temperature decrease in winter in the US, energy use can increase by approximately 15%, and in summer, every 1°C increase means an approximate 10% increase in energy use. The climatic zone implications for offices have been considered in this Guide as indicated in **Section 4.4** and presented in the identified measures (see **Annex A**). In addition, **Box 2.1** provides details on the concept of Degree Days, which is used as a measure of heating and cooling and is important for considering energy use and costs in buildings.

- ***Building maintenance and management***: The management and maintenance of an office's energy using systems can also influence the level of energy demands. Well maintained and managed systems will tend to operate more efficiently and cost-effectively.

These factors all influence the key energy consumption systems in offices which typically comprise:

- Lighting
- Heating, Ventilation and Cooling;
- Water heating;
- Plug-loads such as Computing and IT equipment; and
- Server rooms and data centres.

Box 2.1: Degree Days

A degree day is a measure of heating or cooling. Heating degree days (HDD) are quantitative indices designed to reflect the demand for energy needed to heat a building. A similar index, cooling degree day (CDD), reflects the amount of energy used to cool an office/building.

For example, a one HDD means that the outside temperature is below the temperature required for thermal comfort inside the building by one degree for one day, meaning that heat has to be provided to maintain thermal comfort. The rate at which heat needs to be provided is the rate at which it is being lost to the environment. So for example, for a location with a HDD of 5,000 compared to a second location with a HDD of 10,000, it can be inferred that for a similar building (structure, use and insulation), around twice the energy would be required to heat the building in the second location.

For further information on degree days and how it can be used as part of an energy and carbon management programme, see **www.cibse.org/index.cfm?go=publications.view&item=356** and **www.degreedays.net/**.

2.3 Leased Offices and Key Opportunities for GHG Reductions

Tenants are often the major energy users in office buildings and therefore the opportunity for energy efficiency and GHG reductions is not just confined to the owners of buildings and offices. There are many opportunities for tenants to save energy without major capital investments.

> ***It is a common misconception that to be climate friendly an office has to demonstrate state-of-the-art technology and undergo major capital-intensive refurbishments.***

Some of the best performing offices are older buildings where the office/facility manager has taken measures to optimise the maintenance and management of the office, and therefore improve performance. This Guide therefore focuses on a number of key areas where GHG reductions are possible to UN organisations as tenants (but equally apply to owned offices) as follows:

- ***Energy Supply & Distribution***, where consideration is given to the external supply of energy, the potential for on-site supply, lease agreements and metering;
- ***Operations and Behaviour*** covers the control of peak energy demands, challenging equipment start-up times, ensuring energy bills are fully understood and some behaviour issues such as thermal comfort levels. With respect to behaviour, the focus of this Guide is on the activities and actions office and facility managers can take, rather than the behaviour of office occupants;
- ***Lighting*** is often a major consumer of energy in offices, and the Guide focuses on energy efficient lighting strategies such as optimising lighting levels, lighting upgrades, lighting controls, the use of daylight and exterior lighting;
- ***Heating, Ventilation, Air Conditioning and Refrigeration (HVAC)*** where the Guide covers the principal areas of controls, air distribution, chillers and cooling, water distribution, boilers and hot water, motors and insulation;
- ***Building Envelope*** where consideration is given to doors and external entrances, draught-proofing, window enhancements, solar shading, use of high reflectance materials on the exterior, insulation and green roofs;
- ***Office Equipment*** considering the use of energy efficient equipment, centralising resources and computer/server rooms; and
- ***Refrigerants*** including their management and replacement.

Further details on the individual measures are provided in **Section 4.4.1**, and each measure is contained in **Annex A**.

Chapter 3

Getting Started - Baselining and Benchmarking

UNECA, Addis Ababa, Ethiopia

3.1 Seeking Continuous Improvement

This Chapter focuses on the recommended actions to be taken as a starting point to using this Guide. The success in implementing this Guide, and therefore reducing energy consumption and GHG emissions, is reliant upon appropriate planning and preparation. This starts with ensuring that there is appropriate responsibility and senior management support in place, and then an improvement cycle can be followed starting with initial prioritisation, baseline and benchmarking, followed by the identification of GHG reduction opportunities. The identification opportunities can then be implemented and performance re-assessed against the established baseline and benchmark conditions. The cycle offers the opportunity for continuous improvement and is summarised in **Figure 3.1** below.

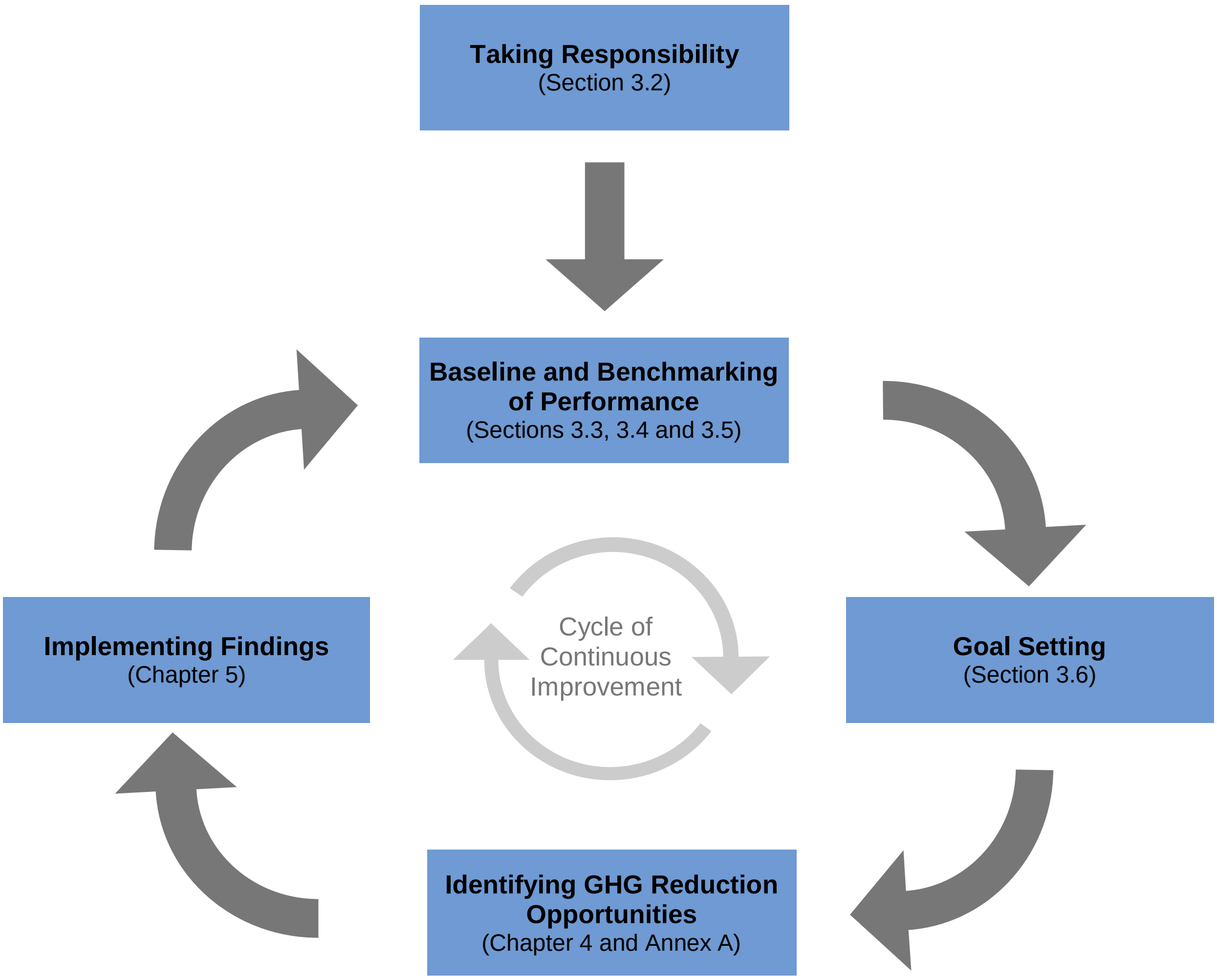


Figure 3.1 Improvement Cycle Diagram

3.2 Taking Responsibility

The first step to be taken is to ensure that an individual is assigned responsibility for managing and leading the climate friendly office initiative. This typically would be the facility/maintenance manager, but does not necessarily need to be this individual. The person can come from the environmental, finance or office management departments, but key attributes for the role must be:

- Energy and enthusiasm for the role to ensure it is successful;
- Has alignment and access to other departments and individuals such as technical, finance, purchasing and other departments that will be involved in the implementation of identified measures;
- Has a senior management 'sponsor'; and
- Understands the particular UN organisation office and activities.


ECLAC, Santiago, Chile

With the responsibility assigned, the person can then begin the process of defining where the UN organisation currently sits with respect to energy and GHG management (see **Section 3.3** below), and follow the cycle defined in **Figure 3.1**.

3.3 Defining the Organisation's Current Position

Use of an energy management matrix to define an organisation's current position is a common approach for energy management, and one that has been adopted for this Guide with a focus on GHG emissions. Using the matrix below in **Table 3.1** will enable understanding of where the UN organisation stands with respect to its current approach to energy and GHG management and will form the basis of developing a more formal GHG management strategy.

Each column should be considered individually, and the box that best describes the organisation's current position marked. These marks should then be connected, which will give an indication of how balanced the approach to energy and GHG management is. Peaks represent where current efforts are more advanced, and troughs where efforts are less advanced. An uneven profile is common, and indicates where attention needs to be focused. The levels defined in the matrix can be summarised as follows:

- ***Level 0***—GHG and energy management is not on the organisation's agenda;
- ***Level 1***—The organisation is just commencing its approach to GHG and energy management;
- ***Level 2***—Energy and GHG management is gaining traction in the organisation;
- ***Level 3***—Energy and GHG management is a priority for the organisation; and

- ***Level 4***—Energy and GHG management is an integrated part of the organisation and its culture.

Level	GHG and Energy Policy	Accountability/ Responsibility	Training	Performance Measurement	Communication	Investment
4	GHG and energy policy, Action Plan and regular review have active commitment of top management	Fully integrated into management structure with clear accountability for energy and GHG issues	Appropriate and comprehensive staff training tailored to identified needs, with evaluation	Comprehensive performance measurement against targets with effective management reporting	Extensive communication of GHG and energy issues within and outside of organisation	Resources routinely committed to GHG and energy efficiency in support of business objectives
3	Formal policy but no active commitment from top management	Clear line management accountability and prioritisation of energy and GHG issues and responsibility for improvement	GHG and energy training targeted at major users following training needs analysis	Regular performance measurement of energy and GHG issues.	Regular staff briefings, performance reporting and GHG and energy promotion	Same appraisal criteria used as for other cost reduction projects
2	Un-adopted policy	Some delegation of responsibility but line management and authority unclear	Ad-hoc internal training for selected people as required	Intermittent monitoring of energy and GHG issues	Some use of company communication mechanisms to promote GHG and energy efficiency	Low or medium cost measures considered if short payback period
1	An unwritten set of guidelines	Informal, mostly focused on energy bills	Technical staff occasionally attend specialist courses	Invoice checking only of energy bills	Ad-hoc informal contacts used to promote GHG and energy efficiency	Only low or no cost measures taken
0	No explicit GHG and energy Policy	No delegation of responsibility for managing GHG and energy	No GHG and energy related staff training provided	No measurement of GHG and energy costs or consumptions	No communication or promotion of GHG and energy issues	No investment in improving GHG and energy efficiency

Table 3.1 GHG and Energy Management Matrix

The illustrations presented in Figure 3.2 indicate an example of an organisation with no explicit GHG and energy policy, and a second organisation with a more mature approach to managing GHG and energy.

Example Organisation 1: No explicit GHG and energy position

Example Organisation 2: Relatively mature approach to GHG and energy management

Figure 3.2 Example organisation profiles using the Energy and GHG Management Matrix (see Table 3.1)

These examples show where areas for improvement within an organisation exist. In the example of Organisation 1, improvement is needed across the board in terms of policy development and implementation, accountability and integration, training, communication and investment. In Organisation 2, areas for improvement include accountability, communication and investment commitments.

3.4 Establishing Baseline Performance

3.4.1 Data Collection

> ***You can't manage what you don't measure. Establishing a baseline of energy use and equivalent GHG emissions is essential.***

Monitoring, analysing and reporting energy consumption are essential elements of an effective GHG and energy management strategy. To establish proper control over energy use and GHG emissions, it is necessary to have information on energy consumption and inputs across the office.

The crucial first step is to determine whether the office energy consumption data is available. For smaller offices and offices located in older buildings, energy costs and consumption may be managed and paid for by the landlord, as opposed to the UN as a tenant. This could be due to the absence of a dedicated energy meter and/or due to contractual arrangements. All offices should assess and determine if they have energy bill responsibility and that the supply of energy to their office is metered. By having meter data, it is the first step to understanding consumption patterns and putting in place GHG reduction strategies. Measure **ESD-02a** (all referenced 'measures' are contained in Annex A) provides further information on the provision of metering, and **ESD-02b** should also be consulted for a further level of data analysis through sub-metering. Finally, **OPS-01** should also be consulted to determine whether billing information is accurate.

The following energy data should be gathered to obtain a comprehensive understanding of the energy use:

- Obtain energy bills for the last two years as a minimum and analyse to understand energy consumption patterns and associated energy costs;
- Determine what the energy bills cover—for example, some landlords do not separately meter heated/cooled air for tenants and the consumption is just charged as a standard service rate or is inclusive within the rental cost;
- Compile sub-metering data if available;
- Compile details of changes in activities, repairs and/or office upgrades; and
- Supplement this data with information gained from the office mapping as described in **Section 3.4.3**.

This data can be collected through simple spreadsheets or for larger offices where more data is available, specific environmental monitoring software can be used. Where the office has a building management system (BMS—see **HVAC-01b**) the data may be available on-line and in real time.

Once the data has been collated, various analyses and plots can be made to assess and understand performance throughout the year and from year to year including:

- Monthly energy consumption trends (fuels, electricity, steam, hot water and chilled water as appropriate);
- Total energy consumption trends (converting energy usage into a standard unit such as kWh or MMBTU);
- Breakdowns by main equipment types (if appropriate data is available, see **Section 3.4.2**); and
- GHG emissions (see **Section 3.4.5**).

Figure 3.3 shows an example energy graphic for monthly consumption for an actual UN office, which shows seasonal consumption trends (compare December through February against April to May) and the impacts of energy efficiency improvements (compare August to December consumptions for 2007 and 2008).

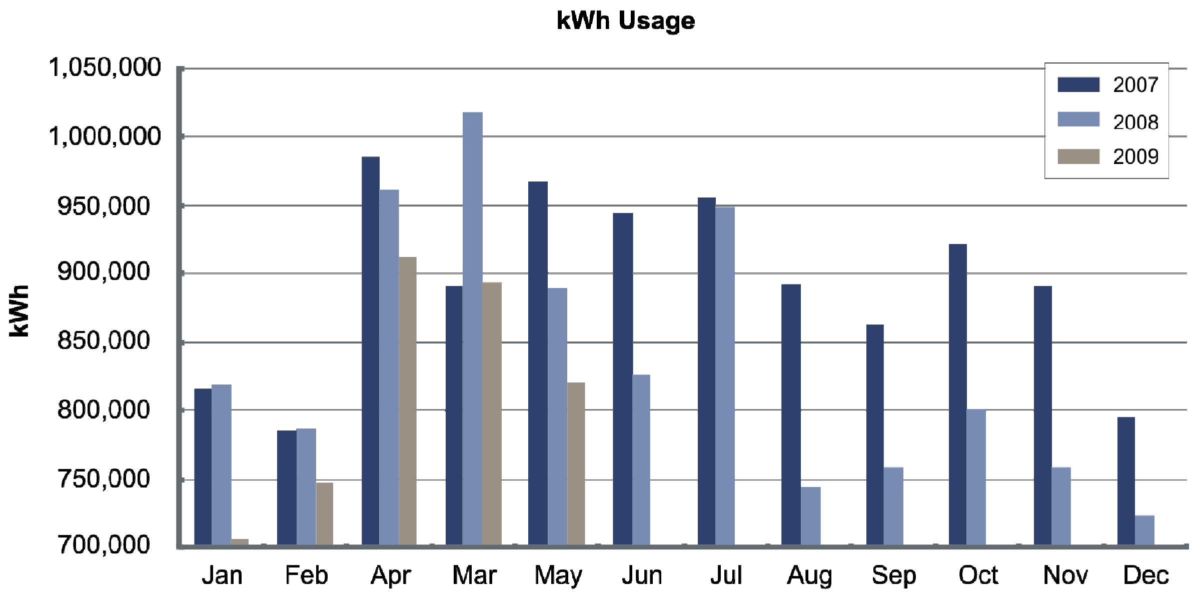


Figure 3.3 Example Energy Data Presentation

3.4.2 Identifying Key Energy Spend and Consumption

Understanding and defining the key energy spend and consumption items is an important consideration in order to focus attention on where the greatest opportunity for savings may exist. Ideally this energy consumption and cost breakdown would come from submetering data (see **ESD-02b**), however in many instances appropriate submetering will not exist. Where clear and useful submetering of energy usage is not available, there are techniques to estimate breakdown of energy usage within an office. Example approaches are provided below:

Electricity Breakdown Only

1. For electrical powered equipment, identify the rated power (kW) and the quantity of equipment. This can normally be taken from the equipment schedule drawings and/or office inventories;

2. Identify the operating hours of the equipment in a year;

3. Insert a load factor (actual power consumption compared to rated power kW). The load factor can be approximated by spot metering, or estimated by assessing how much of the time a piece of equipment/system operates at its maximum load level. This should be done by an appropriately qualified electrician. Regularly spot metering is recommended during different times of the year to get a good overall picture of average kW of equipment.

4. To calculate actual electricity consumption for various equipment, use the following formulae:

$$\text{Power (kWh)} = \text{Rated Power (kW)} \times \text{Hours of Operation (hrs/year)} \times \text{Load Factor (\%)}$$

5. Tabulate power use for all equipment in the office and this will build up a picture of electricity breakdown. Compare the total power estimated (kWh) with utility bills to check assumptions are correct. Otherwise, review hours of operation and diversity to get the estimated electricity breakdown to match actual bill usage. Sometimes there may be equipment missing.

6. The equipment can be classified into groups and a subtotal power consumption for each category calculated. This can be graphed to provide a visual depiction of electricity breakdown (see **Figure 3.5**).

Total Energy Usage Breakdown

- Gas usage or fuel usages are likely separately metered. If this is converted into the same units, then the total energy breakdown can be deduced (rather than just electricity).

- Estimating individual consumption for specific equipment can be difficult due to the need to understand seasonal variations and baseline loads. Specialist help may be needed for these calculations.

Figure 3.4 gives an example spreadsheet approach that could be used and **Figure 3.5** a graphical representation of energy consumption.

Electricity Analysis Calculation - Breakdown

Classification	ID	Description	Floor, Location	kW	Quantity	Schedule	Diversity	kW-Actual	kWh/yr	Subtotal
Boilers		Packaged Air con								
Heating	B-1	1-29F Office 6tons	B7, Mechanical room	15	3	N	0.7	31.5	108486	
Heating	B-2	Mall 2 tons	B7, Mechanical room	8.952	1	O	0.7	6.2664	27447	135933
Chillers										
Cooling	CH-1	Turbo chiller	1~29F office	507	1	P	0.05	23.35	36200	
Cooling	ACH-1	Adsorption Chillers for Office	1-29F Office	9.4	3	P	0.9	25.38	36243	
Cooling	DACH-1	Adsorption Chillers - pump	Mall	7.3	1	Q	0.9	6.57	12141	
Cooling	DACH-2	Adsorption Chillers - pump cooling	1~2F Bank	3.7	1	Q	0.9	3.33	6154	
Cooling	DACH-3	Adsorption Chillers - pump cooling	fitness center	0.75	1	Q	0.9	0.675	1247	91985
Cooling Tower										
Cooling	CT-1	ACH-1	Roof	30	3	P	1	90	128520	
Cooling	CT-2	CH-1 - electric chiller	Roof	22.5	1	P	0.05	1.125	1607	
Cooling	CT-3	DACH-1 Mall	Roof	22.5	2	Q	1	45	83160	
Cooling	CT-4	DACH-2 1st and 2nd floor bank	Roof	5.5	1	Q	1	5.5	10164	
Cooling	CT-5	DACH-3 7th conference room and lobby	Roof	11	1	Q	1	11	20328	
Cooling	CT-6	PAW-1,2	Roof	1.5	1	Q	1	1.5	2772	
Cooling	CT-7	DACH-3 7th conference room and lobby	Roof	11	1	Q	1	11	20328	
Cooling	CT-8	Data Room	Roof	15	2	M	1	30	262800	
Cooling	CT-9	Data Room	Roof	15	2	M	1	30	262800	792479
AHU										
Ventilation	AHU-1	B1,2 Kitchen B&F 1-11, 2-6	B3F AHU Room	11.2	1	B	0.95	10.64	58440	
Ventilation	AHU-2	B1,2F retail 1-5~1-9, 2-14, 2-4~2-8	B3F AHU Room	11.2	1	B	0.95	10.64	58440	
Ventilation	AHU-3	B1,2F retail 1-7, 2-9~2-11, storage	B3F AHU Room	7.7	1	B	0.95	7.315	40178	
Ventilation	AHU-4	B2F Kitchen, Open café	B3F AHU Room	5.9	1	B	0.95	5.605	30785	
Ventilation	AHU-5	B1F kitchen B&F 1-6~1-7	B3F AHU Room	5.9	1	B	0.95	5.605	30785	
Ventilation	AHU-6	B1F kitchen B&F 2-7	B3F AHU Room	5.9	1	B	0.95	5.605	30785	
Ventilation	AHU-7	B1F kitchen B&F 1-8~1-10	B3F AHU Room	14.7	1	B	0.95	13.965	76703	
Ventilation	AHU-8	B1F kitchen B&F 2-9~2-10, storage	B3F AHU Room	20.5	1	B	0.95	19.475	106966	
Ventilation	AHU-9-1	B1F lobby	B3F AHU Room	5.9	1	B	0.95	5.605	30785	

Figure 3.4 Example Electricity Analysis Breakdown

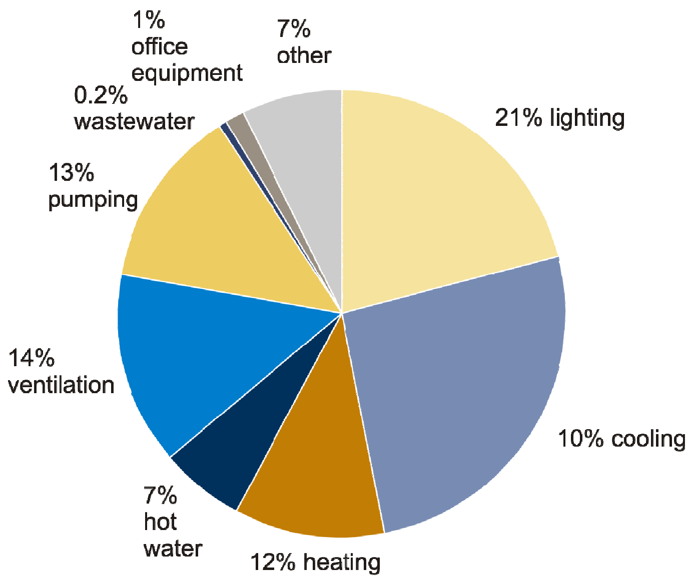


Figure 3.5 Example Summary of Electricity Usage by Equipment/Usage

With this data obtained, the relevant measures in **Annex A** related to the key energy consumers could be immediately consulted to identify immediate opportunities for GHG and energy reductions or conversely the following sections can be consulted for further baseline and benchmarking assessment (Consistent with the assessment options proposed in **Figure 1.1**).

3.4.3 Mapping Office Systems and Activities

As a precursor to identifying GHG reduction opportunities, a thorough understanding of how the office is used, operated and managed/maintained is an essential requirement. By building a map of the key office processes, systems and occupant activities, a good understanding can be gained of current performance and improvement opportunities. Key considerations to be mapped comprise the following, and **Table 3.2** provides more detail under each item:

- Office energy sources;
- Office systems such as lighting, cooling, heating and ventilation;
- Intended office performance;
- Office occupancy and usage patterns;
- Seasonal variations; and
- Lease conditions (if UN organisation is a tenant).

Office Energy Sources	Office Systems
Establish how the office is supplied with energy. The following information should be collected: • Energy supply & source (see ESD-03 in Annex A); • Metering at the office (see ESD-02 in Annex A); • Utility bills for the last 24 months; and • Details on any on-site energy generation sources.	Identify major energy-using systems. The following information should be collected: • Description of each system and how it operates; • Control of system—landlord or UN organisation; • Operating schedules and sequencing; and • Maintenance schedules and any recorded problems.
Lease Conditions	**Seasonal Conditions**
Understand existing lease conditions and restrictions as this may influence the scope and opportunity to implement certain GHG reduction measures, including: • Covenants regarding alterations and reinstatement; • Metering and utility provision (see ESD-02 in Annex A); and • Lease renewal timings (see Section 4.2 and ESD-01).	Understanding the climatic conditions and variations of the office location can help determine which issues may be of concern and which GHG reduction opportunities exist: • Seasonal variations; • Temperature and humidity profiles; and • Other weather patterns and details.
Intended Office Performance	**Occupancy and Usage Patterns**
Define the original design intent and performance expectations of the office. The design conditions can be compared with existing office occupation and usage which can often change when a office is in use. Information to be collected should include: • External temperature design conditions (max & min); • Internal design temperatures (winter and summer); • Fresh air makeup supply rates (total and per person); • Control system operations; and • Lighting levels and switching arrangements.	Obtaining information regarding occupancy and operational hours is important to help create a load profile for the office. Operational hours/occupancy influences the heating and cooling and lighting requirements. The following information should be collected: • Employee numbers on each floor and in each area; • The size of the floor space in square meters; • The equipment used by the employees; • The shifts worked over 24 hour and 7 day weekly cycles; and • The location of these shifts in the office.

Table 3.2: Office Mapping

3.4.4 Legal Compliance

Section 3.4.3 defines the office mapping requirements, however this must be determined in the context of also understanding and defining the minimum legal compliance expectations for the office related to all of the GHG considerations. For example different jurisdictions have different requirements for minimum lighting levels or air ventilation rates, so these must be considered and factored into the preparations for implementing this Guide. It is therefore recommended that a legal compliance table is also drawn up in consideration of building codes, health and safety, worker comfort, any mandatory energy or GHG reporting requirements and other relevant legislation.

3.4.5 Office GHG Inventory

UN organisations are committed to compile an annual GHG inventory, reduce GHG emissions as much as possible and analyse the cost implications of purchasing offsets to become climate neutral. As part of this commitment, a UN Greenhouse Gas Calculator has been developed (see www.unemg.org/sustainableun) to help UN organisations produce comparable greenhouse gas inventories, arising from facilities, operations and travel. The Calculator can be used to compile an office GHG inventory, using data collected in Section 3.4.1 above, representing a crucial step towards reducing emissions. The inventory can serve as a baseline to develop internal strategies for reducing emissions through the implementation of this Guide.

3.5 Benchmarking Performance


ADB, Manila, Philippines

Once an office baseline position has been established, broader benchmarking may provide further information on the office's relative performance when compared to other similar offices, accepted best practices and rating schemes. Some examples of approaches that could be considered include:

- Comparison amongst other offices of UN agencies through shared data via the Inter-Agency Network of Facilities Managers (INFM) platform;

- Of particular relevance to the above is the recently released Common Carbon Metric (by UNEP SBCI, see **www.unep.org/sbci** for further information on the Metric), which provides a standard calculation tool to define measurement, reporting, and verification for GHG emissions associated with the operation of buildings types of particular climate regions. The Common Carbon Metric comprises the performance metrics:

  – Energy Intensity = $kWh/m^2/year$ (kilo Watt hours per square meter per year);

  – Carbon Intensity = $kgCO_2$-e/m^2/year or $kgCO_2$-e/occupant/year (kilograms of carbon dioxide equivalent per square meter or per occupant per year)

- Depending upon location and applicability, there are available energy and GHG benchmarking rating systems such as:

  – EnergyStar in the US (**www.energystar.gov/index.cfm?c=business.bus_index**);

  – Energy Performance Certificates in the EU (**www.diag.org.uk**);

  – National Australian Built Environment Rating System (NABERS) in Australia (**www.nabers.com.au**);

  – Asia-Pacific Economic Cooperation (APEC) Energy Standard Information System (ESIS) (**www.apec-esis.org**)

  – Greenhouse Gas Emission Baselines and Reduction Potential from Buildings in Mexico (**www.unep.org/sbci/pdfs/SBCI-Mexicoreport.pdf**)

  – Greenhouse Gas Emission Baselines and Reduction Potentials from Buildings in South Africa (**www.unep.org/sbci/pdfs/SBCI-SAreport.pdf**)

3.6 Goal Setting

With current performance established through the baseline and benchmarking process, it is then appropriate to consider setting improvement targets. At present, the UN does not define or require specific targets to be established by its organisations, but rather that internal strategies for reducing emissions are developed, and that each organisation's inventory be updated annually to track performance over time.

As a best-practice approach, it is recommended that a series of targets are considered through the development of a GHG reduction policy. The targets could comprise one or a combination of the following:

- A percentage GHG reduction against the total absolute calculated annual emissions for the nominated baseline (e.g. a 30% reduction over three years against the 2009 baseline GHG level);

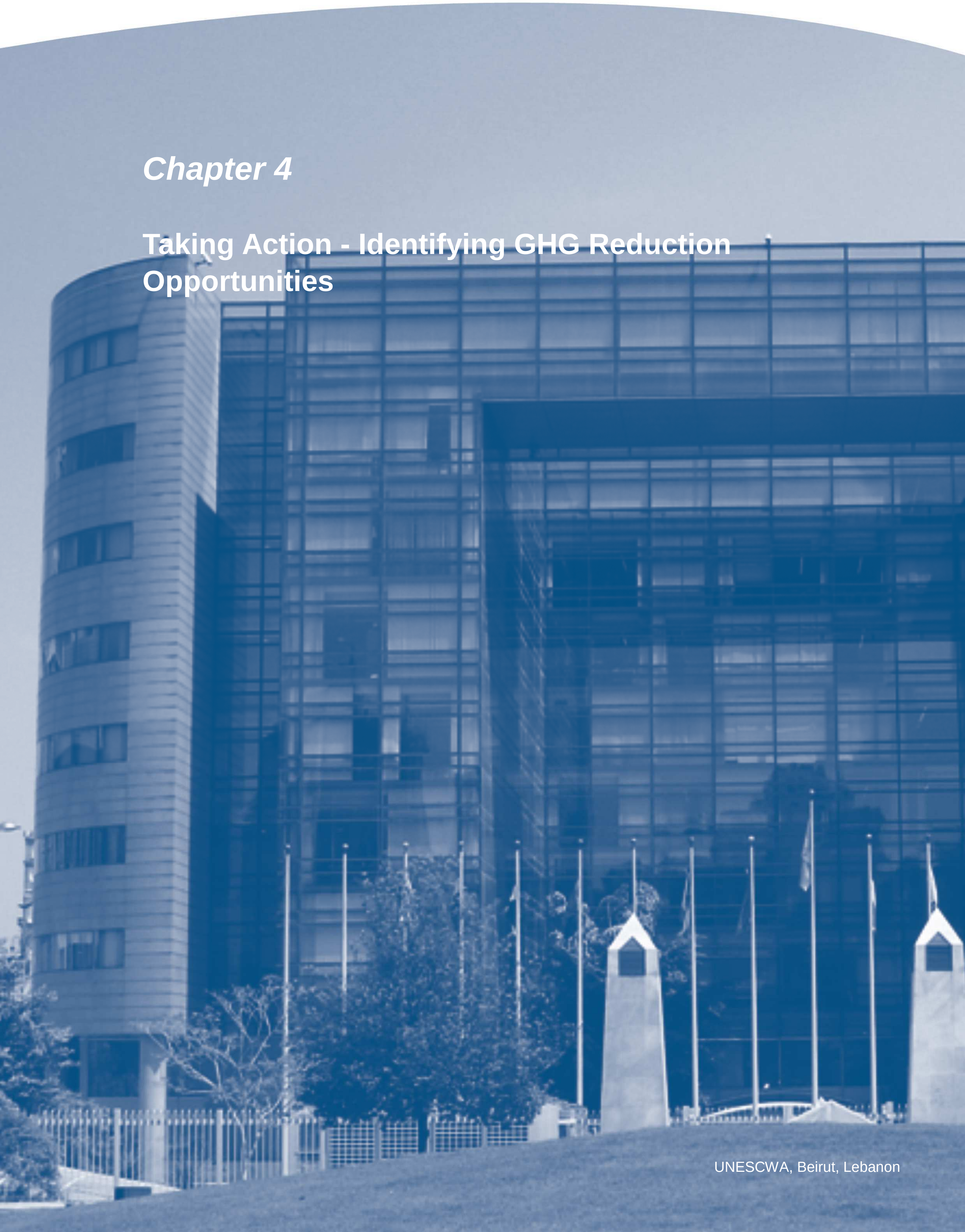
- A percentage reduction against a normalised GHG performance indicator (e.g. a 10% reduction in the GHG emissions per employee, or per square metre of office space); and

- A numerical GHG reduction aim (e.g. a reduction of 100 tonnes of GHG equivalent emissions per calendar year).

All targets must have a baseline year, defined baseline value and a defined period over which the target is to be achieved.

Chapter 4

Taking Action - Identifying GHG Reduction Opportunities



UNESCWA, Beirut, Lebanon

4.1 Implementing Easy Wins

This Guide defines a series of measures that offer the potential to reduce GHG emissions associated with the office environment. By presenting these measures, simple and low cost actions, which often involve occupant behaviour and common sense, must not be overlooked such as the following top 10 easy wins in Box 4.1.

Box 4.1: Top Ten Easy Wins

1. **Turn off lights when rooms are unoccupied or daylight levels are good;**
2. **Activate screensavers on all computing equipment (further information is provided in measure OFF-01 in Annex A);**
3. **Maximise daylighting in the office whilst providing the ability to control glare and heating e.g. the use of blinds (LIG-03 and ENV-06);**
4. **Turn off electrical items at the plug socket and eliminate phantom electricity consumption due to stand-by modes (OFF-01);**
5. **Change the current thermostat settings—consider increasing the temperature by 1°C in summer and reducing by 1°C in winter (see measure OPS-02);**
6. **Eliminate draughts from windows and doors (see measure ENV-02);**
7. **Ensure equipment and systems are not operating during periods of non-activity e.g. night time and weekends;**
8. **Establish procurement policies to only purchase energy efficient equipment (see measure OFF-03);**
9. **Ensure vents, grilles and radiators are not blocked or obstructed (see measure HVAC-02b); and**
10. **Ensure regular and routine maintenance and inspections are undertaken (see section 4.2 below).**

4.2 Commissioning and Maintenance Programme

As part of any efforts to manage and reduce energy consumption and therefore GHG emissions, ensuring a comprehensive approach to commissioning and retro-commissioning of office systems, combined with a thorough and frequent maintenance programme is critical.

Commissioning is a project management practice that provides a quality assurance and control step, through actual testing and documentation to ensure that electrical and mechanical systems are operating and performing at optimum levels and therefore meeting their original design objectives and criteria. The commissioning process is a crucial element of new construction and can be applied to existing buildings and offices that have never been commissioned to restore them to optimal performance.

Retro-commissioning is commissioning of an existing building or office not previously commissioned. Retro-commissioning is a systematic process that identifies low-cost operational and maintenance improvements in offices to bring them up to the design intentions of the current usage. Retro-commissioning typically focuses on energy-using equipment such as HVAC equipment, lighting and related controls and typically focuses on optimising system performance, rather than major equipment replacement and upgrades. This Guide can be considered to be a tool in the retro-commissioning process, but as an essential starting point, organisations should establish current retro-commissioning activities, and compare these against the requirements in the relevant Operation and Maintenance (O&M) plans and manuals for the office. Where gaps exist, the retro-commissioning procedures should be updated to ensure requirements are comprehensively met. The measures presented in this Guide in **Annex A** should also be integrated as appropriate.


FAO, Rome, Italy

Whilst the retro-commissioning programme focuses on optimising performance of systems and equipment, it should be undertaken in parallel with a cleaning and maintenance programme for all equipment. Cleaning and maintenance will ensure optimal and efficient performance and that equipment is operating as designed and life-spans can be maximised.

4.3 Landlord Engagement and Green Leases

The UN organisations are in most instances tenants in their offices. It is recommended that landlords are engaged concerning the UN's commitment to a low energy/carbon office and discussions should be held in terms of collaborating to reduce GHG emissions including the implementation of this Guide. By engaging and working in collaboration with landlords, the UN agencies will be able to achieve greater results compared to working in isolation as a tenant.

> ***By controlling the base building systems, which in most offices includes the supply of heated and cooled air, landlords have an important role to play in the implementation of this Guide and the UN's climate neutral aspirations.***

For existing offices where the opportunity for lease re-negotiation exists, or for new office tenancies, consideration should be given to 'green lease' options that promote and create a partnership between the landlord and tenant (see measure **ESD-01**). A green lease is a lease between the landlord and tenant with an additional set of schedules compared to a 'normal' lease contract, such as a contractual basis for monitoring and improving energy performance, mutual obligations for both tenants and owners to achieve resource efficiency targets (e.g. energy, water, waste) and to minimise the environmental impacts. This ensures that an office operates at an agreed level through regular monitoring and ensures issues can be addressed as they arise.

Both landlords and tenants stand to benefit from green leasing. A landlord may want to reduce building operating costs, make a building more desirable to target tenants and increase the building's value. A tenant may want to reduce operating expenses, increase worker productivity (by improving the working environment) and make a brand statement.

Consideration of a green lease should only be undertaken with appropriate legal advice and with a thorough appraisal and understanding of the potential economical implications of the lease obligations. Some examples of issues for consideration include:

- Allowance to make energy-efficiency upgrades, and determination of the cost allocation for these upgrades;
- Issues related to rights of entry, interruptions to utility service and/or tenant's business operations;
- Lease structure - consideration of whether the lease costing structure will change as energy efficiency improvements are made;
- Sharing of energy performance data;
- Reinstatement – the lease should reflect the fact that the tenant will not be required to reinstate or remove alterations that have been made to achieve energy efficient measures/targets;
- Separate Metering - provisions can be included in the lease to provide that the landlord will ensure that the different premises are separately metered for electricity, gas and water services; and
- Financial Incentives - there could be financial incentives for a tenant who hits their 'green targets'. Landlords could face penalties if they fail to fulfil agreed obligations in terms of energy efficient improvements or meeting required energy efficient ratings for the building.

4.4 GHG Reduction Opportunities

4.4.1 Individual Measures

A series of individual measures have been defined as part of this Guide that can either enable GHG reductions, or facilitate such reductions. These measures focus on the following key areas where GHG reductions are possible:

- Energy Supply & Distribution (ESD);
- Operations and Behaviour (OPS);
- Lighting (LIG);
- Heating, Ventilation, Air Conditioning and Refrigeration (HVAC);
- Building Envelope (ENV);
- Office Equipment (OFF); and
- GHG Compounds and Refrigerants (REF).

The full list of Measures is summarised in **Table 4.1** and **Annex A** contains each Measure in detail, and the presentation of each measure is shown below in **Figure 4.1**. The associated key must be consulted for each measure:

Energy Supply & Distribution (ESD)	
ESD-01: Lease Negotiation	
ESD-02: Metering	(a) Main Office Metering
	(b) Sub-Metering
ESD-03: External Supply	(a) Energy Tariffs
	(b) Green Power
	(c) Utility Rebate Programmes
ESD-04: On-Site Energy Supply	(a) Co-generation
	(b) Renewable Energy
Operations & Behaviour (OPS)	
OPS-01: Understanding Energy Bills	
OPS-02: Thermal Comfort Settings	
OPS-03: Equipment Start-Up	(a) Minimise Peak Loading
	(b) Equipment Operation Times
Lighting (LIG)	
LIG-01: Lighting Levels	(a) Reflectance
	(b) Reduce Excessive Lighting
LIG-02: Lighting Controls	
LIG-03: Daylighting	
LIG-04: Lighting Upgrades	(a) Lamps
	(b) Ballasts
	(c) Emergency Lighting
	(d) Down-Lighting
LIG-05: Exterior Lighting	
Building Envelope (ENV)	
ENV-01: Doors & Entrances	
ENV-02: Draught-proofing	
ENV-03: Window Films	
ENV-04: Glazing Options	
ENV-05: Natural Ventilation	
ENV-06: Solar Shading	
ENV-07: Solar Reflective Surfaces	
ENV-08: Insulation	
ENV-09: Green Roofs	
GHG Compounds and Refrigerants (REF)	
REF-01: GHG Compound Management	
REF-02: Replacement of GHG Containing Equipment	

Heating, Ventilation, Air Conditioning & Refrigeration (HVAC)	
HVAC-01: Controls	(a) Thermostats
	(b) BMS
HVAC-02: Air Distribution	(a) Air Balancing
	(b) Obstructions
	(c) Filter Cleaning & Upgrade
	(d) Eliminate Ductwork Leaks
	(e) Heat Exchanger Coils
	(f) Damper Blades & Linkages
	(g) Fans
	(h) Supply Air Temperature Reset
	(i) VAV
HVAC-03: Air Economiser	
HVAC-04: Chillers & Cooling	(a) Water System Treatment
	(b) Chiller Maintenance
	(c) Water-side Economiser
	(d) Chilled Water Reset
	(e) Cooling Towers
	(f) Variable Primary Flow
	(g) Chiller Retrofit
HVAC-05: Boilers & Heating	(a) Domestic Hot Water
	(b) Boiler Maintenance
	(c) Demand Needs
	(d) Hot Water Reset
	(e) Insulation
	(f) Flue-Shut-Off Damper
	(g) Oxygen Trimming
	(h) Economiser
HVAC-06: Motors	
Office Equipment (OFF)	
OFF-01: Equipment Settings	
OFF-02: Equipment Centralisation	
OFF-03: Energy Efficient Equipment	
OFF-04: Server Rooms	

Table 4.1 Table of Measures (see Annex A for the full details)

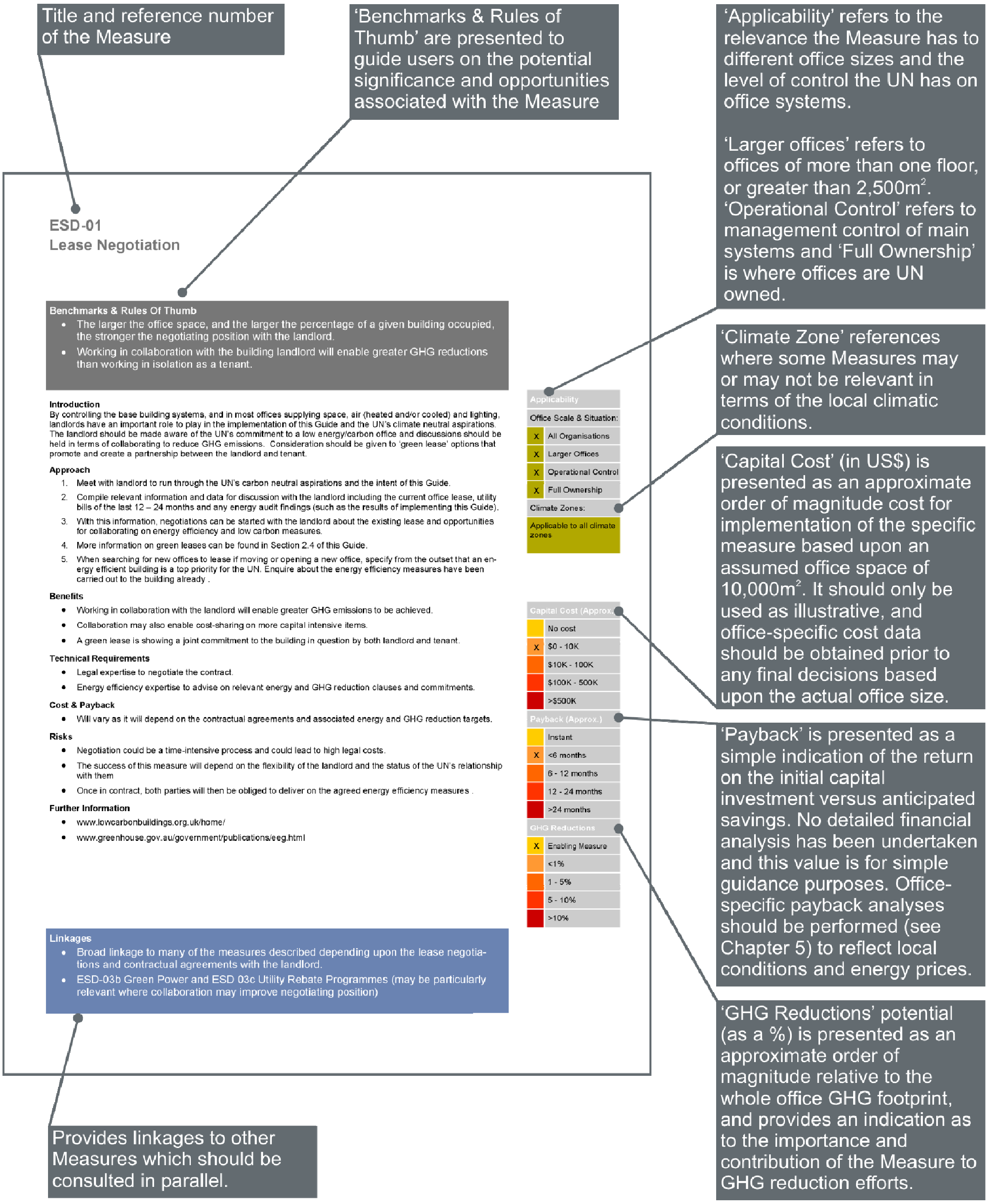


Figure 4.1—Legend describing the individual measures presented in Annex A

4.4.2 Selection of Applicable Measures

The measures presented consider a range of scenarios in order to reflect the diversity that will exist across the UN organisation and partner organisation offices such as:

- Varying scale and size of office;
- Varying access and control to key energy consuming systems;
- Differing geographical and climatic conditions;
- Differing occupation patterns and use; and
- Varying levels of progress to date in managing energy and GHG emissions.

To reflect this diversity of office type, location and occupation of the UN organisations, the flow-chart in **Figure 4.2** guides users through the measures to be considered and prioritised.

4.5 Health & Safety

Prior to undertaking the office assessment by following the measures in the Guide, a health and safety plan should be developed prior to inspecting and assessing existing plant and equipment. Important considerations that must be evaluated and appropriate mitigation plans put in place include:

- Working from height;
- Arc flash and electrical isolation of equipment and avoidance of moving parts (lock-out and tag-out safety procedures);
- Avoiding exposure to potentially harmful compounds e.g. asbestos, refrigerants or water treatment chemicals;
- Follow all supplier safety procedures; and
- Trip and fall hazards.

Item	Question	Answer	All UN Organisations to consider		Larger Offices *(multiple floors)*		Operational Control of Office System(s)		Building Ownership and Full Control
OFFICE CONTEXT									
1. Lease:	Has the landlord been engaged relating to GHG and energy issues?	No	Chapter 4.2 ESD-01						
2. Metering:	Is the office metered and do the UN organisation pay the bills directly?	No	ESD-02a	Consider submetering	ESD -2b				
3. Bills:	Has the accuracy of the energy bills been verified?	No	OPS-01						
4. Energy Market:	Is the office located in a deregulated electricity market?	Yes	ESD-03a, b and c						
GENERAL OFFICE MANAGEMENT									
5. Thermal Comfort:	Have the thermostat and other office controls been checked?	No	OPS-02 HVAC-01a	Consider BMS			HVAC-01b		
6. Housekeeping	Have vents & diffusers been cleared of obstructions, and draughts sealed?	No	HVAC-02b ENV-02						
LIGHTING									
7. Lighting:	Have lighting improvement opportunities been considered?	No	LIG-01, 02, 03 and 04	Consider external lighting			LIG-05		
OFFICE & COMPUTING EQUIPMENT									
8. Office Equipment:	Has the energy efficiency of office equipment been considered?	No	OFF-01, 02 and 03	Offices with server rooms	OFF-04				
MAJOR HVAC SYSTEMS									
9. Operational Control:	Does UN have some control over the air distribution system?	Yes	OPS-03 (switching on lights, A/C etc)	Consider for larger offices	HVAC - 02d, f and h	Where full operational control exists	OPS-03, HVAC-02a, c, e, g, HVAC 03 & 06	And where office owned	HVAC-02i
10. Cooling Systems:	Does the office have a cooling system under UN control?	Yes					HVAC-04a - f, REF-01 & 02	And where office owned	HVAC-04 g
11. Heating Systems & Hot Water:	Does the office have heating/boiler systems & hot water under UN control?	Yes		Consider for larger offices	HVAC - 05a and d		HVAC-05b, c, e, and f	And where office owned	HVAC-05g and h
OFFICE ENVELOPE & EXTERIOR									
12. Envelope:	Have insulation and shading measures been considered?	No	ENV-01, 03, 05 and 06 (as applicable)	Where full operational control exists			ENV-04, 05, 07, and 08	And where office owned	ENV-09
13. On-Site Energy:	Have on-site energy sources been considered?	No					ESD-04b	And where office owned	ESD-04a

Figure 4.2 Decision Matrix for Selection of Applicable Measures

Chapter 5

Implementation of Findings - Prioritisation and Justification

UNESCO, Paris, France

5. Implementation of Findings — Prioritisation and Justification

5.1 Implementation of Measures

Once the office has been assessed against the relevant measures described in **Annex A**, the next step is to establish an implementation plan. The identified improvement measures will need to be prioritised against the respective UN organization's criteria such as cost, GHG reduction potential, overall environmental improvement and practicality. The 'no cost' items can be implemented immediately, however many of the other measures will involve some form of investment. The following sections provide some further guidance on the issues that must be considered as part of the implementation plan development.

5.2 Legal Compliance and Health & Safety

Consistent with **Sections 3.4.4 and 4.5**, it is important that as part of any proposed improvement measure the associated legal compliance and health and safety considerations are fully considered.

5.3 Investment Approach

Consideration should be given to which approach the organisation will take with respect to investment approaches. Two main routes are recommended:

- The organisation will fund the improvement and GHG reduction measures directly, which means each measure will need to be appropriately evaluated (see **Section 5.4** below); or

- Seek third party financing through an energy service company (also referred to as ESCO's or performance contracting) where this third party will invest in the measure and receive payment through alternative means such as shared energy savings accrued. This latter option obviously only works where energy savings are predicted, however facility and office managers should discuss the feasibility of this option with their procurement and finance teams.

5.4 Financial Evaluation

Without an appropriate financial evaluation of the improvement measures to be made, it is unlikely that approval will be gained. Such an evaluation should consider the investment commitments needed, the benefits arising from the investment and the associated risk in this investment. Different organisations have differing approaches to assessing financial commitments, and several techniques exist such as average rate of return, payback period, internal rate of return and net present value (Note: For the purposes of the measures presented in **Annex A**, a simple payback estimate has been used). This is purely indicative and must not be relied upon as an accurate assessment. Organisations must perform their own financial assessments based upon the specifics of their offices to determine the financial performance of given measures).

It is not the intent of this Guide to present detailed explanations of the financial techniques available, therefore financial support should be sought as part of the implementation assessment to determine the best approach to use, the associated hurdle rates of the organisation (referring to the point at which an investment is deemed acceptable) and any other organisation-specific evaluations that need to be undertaken. In preparing for such assessments, ensure the following data is available to support calculations:

- The price of energy (consider off-peak tariffs, demand charges etc);
- Capital costs for implementation items (quotations may need to be obtained from contractors/suppliers);
- Energy saving estimates;
- Other indirect energy or other environmental savings. For example, improving lighting (see measures **LIG-01 to 04**) reduces the cooling load in an office which in turn reduces the cooling energy costs;
- Other associated costs such as labour and maintenance requirements.


IMF, Washington DC, USA

5.5 Prioritisation of Measures

With a better understanding of the financial aspects of the improvements proposed, the measures to be implemented should then be ranked in order of priority. This prioritisation will be organisation-specific in terms of the factors that rate highest, and could include consideration of the following:

- The overall capital cost;
- The calculated payback in terms of the direct cost savings as well as indirect savings such as cascade savings or reduced O&M costs;
- The level of energy and GHG reduction to be achieved;
- The timescale of the implementation measures (could be particularly important if leases are due to expire);
- The current state of repair of the measure in question;
- Potential staff acceptance;
- Ease of implementation and potential for disruption; and
- Potential linkage with any known landlord improvements to be made.

5.6 Tenancy Considerations

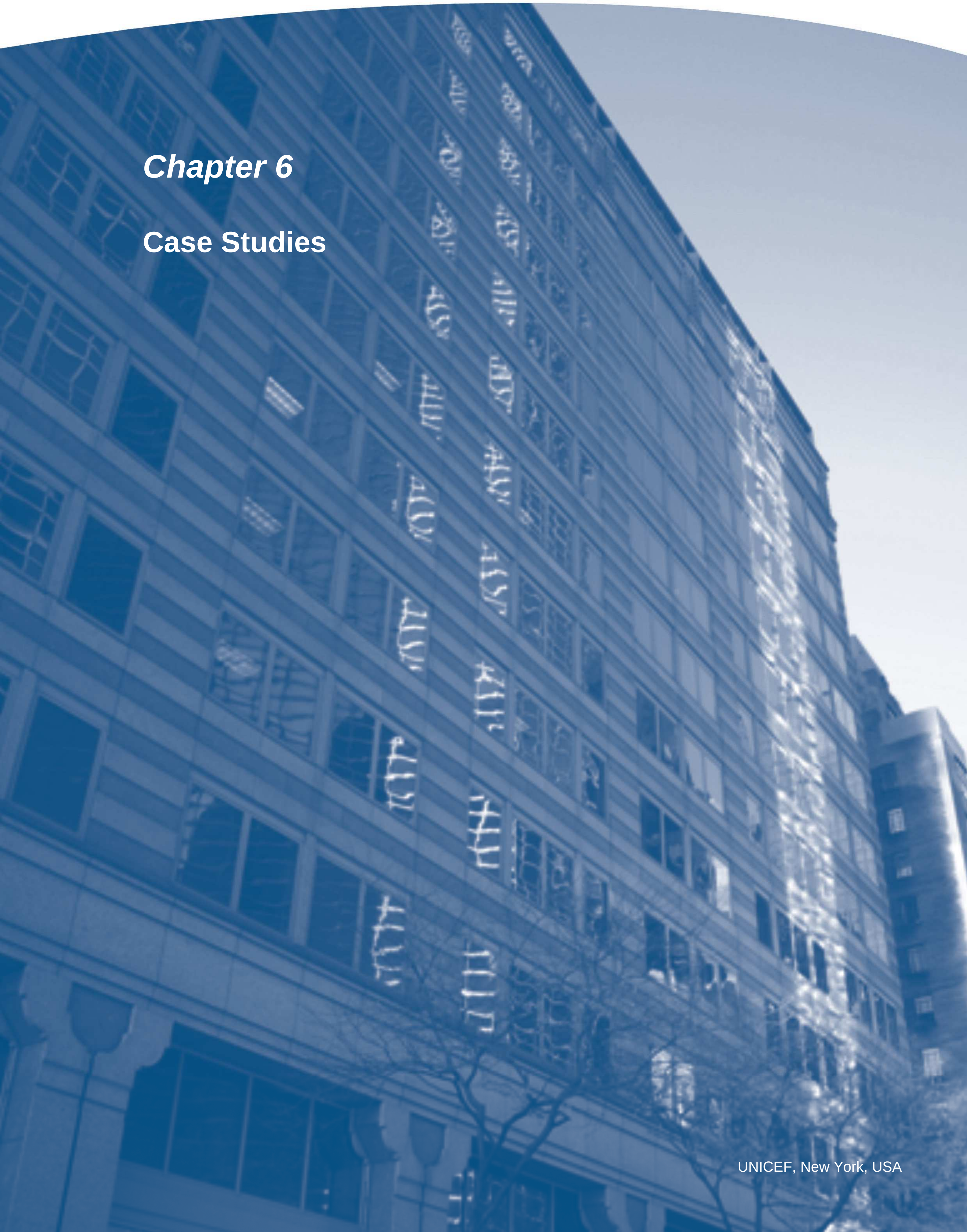
Finally, it is important to remember and understand whether there are any barriers that may exist where the organisation is a tenant. Examples may include:

- Access constraints to key infrastructure of the building;
- Uncooperative landlords;
- ‘Make good’ clauses that must be adhered to on expiry of the lease;
- Unfavourable terms of the lease; and
- Inadequate metering systems and monitoring plans.

Further discussion on lease issues and landlord engagement has been provided in **Section 4.3**.

Chapter 6

Case Studies



UNICEF, New York, USA

6.1 Introduction

As part of the Guide development, three UN offices were visited to act as case studies for the testing and implementation of the recommended approaches. For all three case studies, the Guide (in its early draft form) was used as a basis for an energy and GHG assessment. The approaches outlined in **Sections 3.4.1** and **3.4.2** were used to provide an initial understanding of the offices' energy consumption and the main energy uses, which was used as a basis to focus attention on the highest energy consumers using the measures presented in **Annex A**.

6.2 African Development Bank, Tunis, Tunisia

6.2.1 Introduction

The African Development Bank (AfDB) in Tunis was selected as a case study. AfDB are a tenant and are looking to relocate within approximately 3 years of the time of the assessment. This short time horizon for the existing offices influenced the measures that were assessed and deemed relevant. AfDB has operational control of its buildings, therefore the key focus was on the management and operation of equipment, as opposed to upgrades or replacement. Issues such as equipment operating times, operational efficiency, draught-exclusion for windows and turning off equipment are examples of the measures assessed, and are described in more detail below.

With an impending move, the option for lease negotiation for a prospective new office location was a particular item for discussion in the office assessment. Many of the measures promoted in the Guide were highlighted as being important for lease discussions, with a possible option for a green lease, to ensure an energy efficient and climate friendly new AfDB headquarters.

AfDB, Tunis, Tunisia

6.2.2 Office Description

The African Development Bank (AfDB) comprises two buildings, which are known as the ATR and the EPI. The ATR building was constructed over between 1997 and 2001. The EPI building was constructed in 2003. The ATR building is currently owned by Mohamed Driss and the EPI by la Sociéte EPARGNE PARTENARIAT INVESTISSEMENT "EPI". The AfDB occupies the whole space in both buildings, including basement floors. The ATR building is approximately 19,000m^2 and the EPI building is approximately 23,200m^2. In total, as of 2009, there are approximately 1,400 occupants and the typical working hours are 08.30 to 16.30, 5 days a week although working outside of these hours can occur. The lease on both buildings is a 1 year renewable lease.

The layout of both buildings can be described as follows:

- The ATR building has 8 floors of offices across 3 towers and the EPI building has 14 floors of offices (although one floor was unoccupied when the office assessment was undertaken);
- The EPI ground floor contains the lobby, main reception, security and meetings rooms;
- The ATR has a large conference room and trading floor on the ground floor; and
- The basement of each building is occupied by a car park.

6.2.3 Key Energy Systems

The key energy systems at the EPI and ATR buildings can be summarised as follows:

- The air conditioning within the buildings consists of split DX units which provide cooling in the summer and some space heating during the winter months. Some space heating is provided through on-peak electric convector heaters although the usage is not extensive due to the mild winters that occur in the region.
- With the exception of meeting room areas which are centrally controlled the local office units are manually switched on and off and have local temperature controls. The bank is currently considering the expansion of the building control system that controls the meeting rooms.
- Lighting is mainly provided through T8 fluorescent fittings using conventional ballasts although some lighting in common areas and meeting rooms is provided through halogen down-lighters which have a high energy use and subsequent increase in the air conditioning load. The lighting is manually switched although the bank is currently considering installing automatic occupancy controls in common areas.
- Although the buildings are air conditioned they are also naturally ventilated through opening windows which can conflict with the operation of the air conditioning units.
- Efforts to reduce solar gain have been made through installation of some external solar films and internal blind systems.

The buildings consumed approximately 6.6 million kWh with an annual cost of approximately US$619,500 between April 2008 and March 2009. The energy utilisation index was calculated to be 153kWh/m^2 for the ATR building and 160kWh/m^2 for the EPI building. Specific information to benchmark office buildings in Tunisia is not available but when compared with available information for European office facilities the buildings performance is 'good'.

6.2.4 Energy Analysis

The breakdown of energy was calculated based on installed power of different equipment items, occupancy hours and other assumptions. The top three electricity consuming items are cooling/heating (30.8%) and lights (43.0%), with computers making up 9%. Other office equipment and miscellaneous items account for 5% each. These were identified as key areas for focusing on energy efficiency within the building, however as described, the proposed move in less that three years limited the available opportunities that could be considered. Figure 6.2 details the estimated energy breakdown.

6.2.5 GHG Reduction Opportunities

A total of 20 key proposed cost reduction opportunities were identified which focus on reducing consumption in the main energy consuming areas of which 15 opportunities were considered in detail and the remaining 5 considered for further detailed investigation.

The key GHG and energy saving opportunities focused on improving the control of the air conditioning and lighting systems through improved awareness and installation of centralised controls, changing the cleaning hours from night to day to reduce the energy use at night and replacing some inefficient halogen down lighting fittings with LED units.

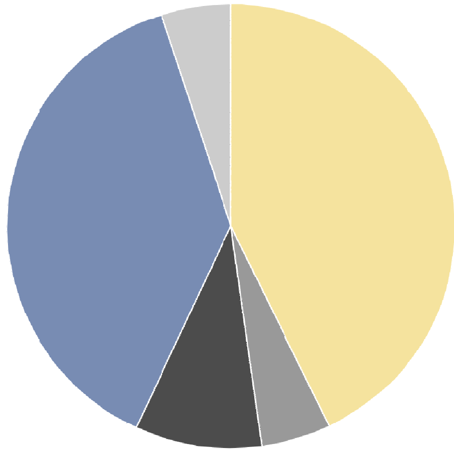


Figure 6.2 Energy Breakdown for AfDB

6.2.6 Summary

The Guide was used as a basis for a building assessment to identify the opportunities for GHG reduction. If the 15 costed key measures are implemented the total energy reduction potential is 2,147,500 KWh per annum or 32% of existing consumption. GHG reduction potential is approximately 1,034 tonnes of CO_2 per annum. Total per annum cost savings are US$195,800. Total capital investment required is US$285,200 giving a simple payback of 1.5 years.

These potential improvements identified for the AfDB buildings are summarised in the table below and were divided into four categories based on indicative payback and/or capital investment to achieve the estimated energy savings:

- Green (Low Hanging Fruit) – payback of less than 1 year, and/or capital investment less than $5,000;
- Yellow (Medium Hanging Fruit) – payback of less than 3 years, and/or capital investment between $5,000 and $250,000; and
- Red (High Hanging Fruit) – payback of 3-5 years, and/or capital investment greater than $250,000.

Proposal Idea	Reference Measure	Estimated Capital Cost (US$)	Savings per annum (US$)	Payback	Tonne CO_2 reduction per annum	Priority
Low Hanging Fruit						
Lease negotiation	ESD-01	$0	$22,800	Instant	120	
Continue with refrigeration equipment replacement	REF-02	$0	$2,315	Instant	12	
Establish agreed room temperature for summer and winter	OPS-02	$1,425	$13,900	1 month	73	
Programme to switch off lighting and air conditioning systems.	LIG-02	$2,850	$16,870	2 months	89	
Monitoring and targeting procedures to identify high power consumption areas	ESD-02b	$2,850	$6,020	6 months	32	
Prevention of simultaneous heating and cooling in adjacent offices	HVAC-02h	$1,425	$2,315	6 months	12	
Day-time cleaning to allow lighting and air conditioning to be switched off at night	OPS-03	$7,125	$12,050	7 months	64	
Ensure windows closed and draught-proofed	ENV-02	$1,425	$2,315	8 months	12	
Maintenance procedures to improve chiller operating efficiency	HVAC-04b	$4,275	$4,630	11 months	24	
Medium Hanging Fruit						
Reduce number of electric portable heaters	-	$285	$185	1.6 years	1.0	
Install automatic lighting controls with PIR / microwave sensors in common areas	LIG-02	$71,230	$39,025	1.9 years	206	
Replace manual switching and temperature control with automatic controls	HVAC-01	$142,460	$57,990	2.4 years	306	
High Hanging Fruit						
Replace 35W halogen downlighters with LED units	LIG-04d	$14,250	$5,200	2.7 years	27	
Install draught lobby or air curtain at main entrance points	ENV-01	$7,125	$2,315	3 years	12	
Switch off computers and other office equipment when not required	OFF-01	$28,500	$7,900	3.6 years	42	

Table 6.2 Proposed GHG Reduction Projects for AfDB

6.3 UNESCAP, Bangkok, Thailand

6.3.1 Introduction

The UN's Bangkok Complex occupied by the Economic and Social Commission for Asia and the Pacific (UNESCAP) was also selected. The UN holds a long term lease from the Government of Thailand for the complex, however UNESCAP has full operational control and effective ownership of the buildings to allow upgrades and improvements to be made.


ESCAP, Bangkok, Thailand

As a consequence, many of the Guide measures are relevant to the complex, however during the assessment, it was noted that the controls, management and maintenance of the complex was good and therefore many of these related measures were not assessed. Further assessment of the energy supply and distribution measures was recommended, although this acknowledges there may be limitations in the current opportunities within the current Thai electricity markets. The operations and behaviour measures were relevant and in particular equipment operating times and thermal comfort settings, as well as lighting upgrades. A number of opportunities were identified under air distribution and the chillers, and given the Bangkok climate, most of the boiler and heating measures were not applicable. Office equipment and the building envelope were not appraised in detail as part of the assessment.

6.3.2 Office Description

The UN Bangkok Complex was constructed in phases and consists of Secretariat and Service Buildings constructed in 1972 and United Nationals Conference Centre (UNCC) constructed in 1989. The UN holds a long term lease from the Government of Thailand for the complex with the tenant being UNESCAP.

The total complex floor area is 87,232 m^2. This consists of 33,489 m^2 of occupied areas, 24,534 m^2 of common areas, 28,221 m^2 parking spaces and 988 m^2 other spaces. Building usage is described as follows:

- Secretariat building 16 floors;
- Service building, 5 floors and roof top where cooling towers are located;
- UNCC 3 floors, used as conference centre, meeting rooms, document storage areas, restaurants, 4 escalators;
- Basement underground parking;
- Basement wastewater treatment plant;

- Basement mechanical room; and
- 18 elevators within the complex.

The building space serves approximately 1350 staff, and operates between 10 to 12 hours a day, with longer operating hours during special conference events.

6.3.3 Key Energy Systems

Cooling is provided by air handlers on a floor by floor basis that utilise a central chilled water system. There are three 900-ton Carrier Chillers and two-600 ton York Chillers. On a day to day basis, effectively only one of the Carrier chillers are being operated for the majority of the time. Therefore a typical cooling load is 900-tons. During hot days, a second chiller (600-ton York) may be used depending on cooling load, or alternatively used in stead of the Carrier during part load times.

The weather conditions in Bangkok are such that no heating is required for the building. Ventilation is provided by air handling units. Outside air is drawn in by a separate make up air supply system, which is preconditioned to 16^0C, and supplied into the mechanical room. The make up air is not ducted directly to each AHU's, instead there is a damper at the inlet which lets air enter the system. However, during the site visit, these dampers were observed to be closed in the conference centre make-up AHU's and thus limited fresh air is being supplied to the occupied spaces. The AHU's are constant air volume type (not variable air volume or flow controlled). A best practice is to put some motorised actuators and ducting to deliver air appropriately together with controls to provide demand controlled ventilation. This is already begun in the secretariat and service building where AHU's have been retrofitted with actuators on the dampers with CO_2 demand control (CO_2 sensors in the return duct).

The building controls are provided by a building automation system (BAS), which uses digital control with graphical interface. A new lighting control system called "Lumisys" is reportedly being installed which integrates into the BAS.

There is one 69kV power feeder which connected to two transformers rated at 5 MVA that reduces the incoming electricity to 416V.

6.3.3 Energy Analysis

The breakdown of energy was calculated based on installed power of different equipment items, occupancy hours and other assumptions. The top three electricity consuming items are lighting (39.1%), Chillers (17.2%) and AHU (23.6%) as shown in **Figure 6.3**. These are areas of focus when looking to improve energy efficiency within the building.

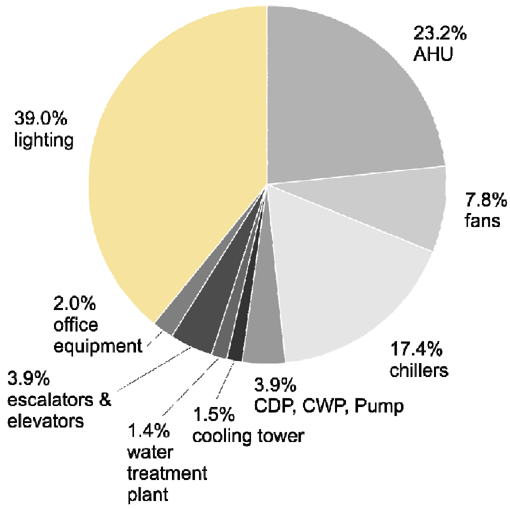


Figure 6.3 Energy Breakdown for UN Bangkok Complex

6.3.4 GHG Reduction Opportunities

A total of 14 key proposed cost reduction opportunities were identified which focus on reducing consumption in the main energy consuming areas. Many other small opportunities exist at the site to reduce consumption and further recommendations for actions UN Bangkok should pursue are also provided. A detailed assessment is required to fully evaluate the extent of these smaller opportunities.

One of the key energy saving opportunities for the building is lighting upgrades and optimisation. A systematic review of the buildings' lighting fixtures and lamps for higher efficiency, lower wattage options should be undertaken. Also review options to reduce the operating hours of lighting to only when the spaces are occupied. This is being targeted as part of the Lumisys lighting control upgrade. Other proposals include introducing earth hour campaign by switching lights off for 3/4 hour at lunch time.

After lighting has been optimized to reduce its impact on building HVAC the focus then turns to HVAC systems optimization. The building is over equipped with 5 chillers with only 1 operating typically. Operational staff should switch to using the higher efficiency York chillers instead and undertake an engineering study to improve its efficiency further. This could include installing Variable Speed Drives to optimise chilled water primary pumping and reducing chilled water temperature set-point to further reduce pumping costs.

6.3.5 Summary

It is provisionally estimated that the implementation of the priority 14 measures identified at no or little capital investment, could reduce overall consumption by approximately 30% and result in savings worth US$278,000 per annum. This would reduce total energy consumption by 3 million kWh with a GHG potential reduction of 1,530 tones CO_2e per annum.

The potential improvements identified for the UN Bangkok building are summarised in the table below and have been divided into three categories based on indicative payback and/or capital investment to achieve the estimated energy savings:

- Green (Low Hanging Fruit) – payback of less than 1 year, and/or capital investment less than $5,000;
- Yellow (Medium Hanging Fruit) – payback of less than 3 years, and/or capital investment between $5,000 and $250,000; and
- Red (High Hanging Fruit) – payback of 3-5 years, and/or capital investment greater than $250,000.

Proposal Idea	Reference Measure	Estimated Capital Cost (US$)	Savings per annum (US$)	Payback	Tonne CO_2 reduction per annum	Priority
Low Hanging Fruit						
Review of equipment start-up and switch -off times	OPS-03b	$0	$23,868	Immediate	139	
Reduce excessive lighting	LIG-01b	$0	$116,553	Immediate	681	
Earth Hour	-	$0	$27,866	Immediate	163	
Replacement of light bulbs to lower watt-age	LIG-04a	$70,000	$69,664	1 year	407	
Operate York Chillers instead of Carrier	-	TBD	$39,760	Immediate	141	
Medium Hanging Fruit						
VAV Conversion for AHU's	HVAC-02i	$79,990	$41,127	1.9 years	240	
Ventilation retrocomissioning	HVAC-02	$100,000	$80,125	1.2 years	468	
Chilled Water Temperature Re-set	HVAC-04d	-	$3,473	Immediate	20	
Chilled water pumping power reduction	HVAC-06	$10,000	$7,898	-	46	
AHU fan power reduction	HVAC-02g	$80,000	$98,606	-	576	
Condenser pumping power reduction	-	$18,000	$15,366	1.2	90	
High Hanging Fruit						
Peak electricity charge reduction (ice storage)	-	$194,400	$23,433	8.3	-	
Replacement of lighting fixtures and bal-last, LEDs	LIG-04	$1,494,600	$162,550	9.2	949	
Upgrade York Chillers with VSD and optimised technology	HVAC-04g	$100,000	$6,300	15	37	

Table 6.3 Proposed GHG Reduction Projects for the UN Bangkok Complex

6.4 UNHCR, Geneva, Switzerland

6.4.1 Introduction

UNHCR, Geneva, Switzerland

The UNHCR has begun the process of developing its GHG footprint and an associated strategy to reduce its GHG emissions and improve its overall sustainability, through different initiatives at headquarters and in the field. The UNHCR headquarters in Geneva have been an initial focus of this work, which includes among others the development of a green office programme. For this case study, the Geneva headquarters main building has been subject to an assessment to determine its GHG footprint in 2009, and then an energy assessment, using the Guide as a framework, to determine the opportunities for GHG reduction. The GHG assessment for this case study only considers scope 1 and 2 emissions (see **Section 2.2**), although as part of UNHCR's GHG study scope 3 emissions have been considered.

The UNHCR Geneva headquarters comprises primarily one main building and one annex, and one warehouse. This case study focuses on the main office building called MBT, and presents "a before" and "an after" GHG footprint based upon the predicted reduction in GHG emissions using the Guide.

6.4.2 Office Description

The MBT office was opened in 1995 and provides office space for approximately 720 staff. The building has seven (7) main office floors plus three (3) basement levels containing car parking, storage, refrigeration, boilers and HVAC plant. The facility has a floor area estimated at 21,278m^2 in addition to 2,480 m2 for parking, and storage, and technical rooms in the basement. The core hours of occupation are between 7am and 7pm, Monday to Friday.

The building features a central glazed atrium which extends from the ground floor reception level to the 7th floor roof area. Offices are located on three sides around the atrium. The building was designed to be naturally ventilated with louvers in the front of the building and in the roof space of the atrium providing a level of air movement. This is supplemented by the normal HVAC system which provides tempered / cooled air to the perimeter office areas .

6.4.3 Key Energy Systems

The building was designed to have a low specific energy consumption when compared to other office facilities. In particular the building atrium captures heat during the winter months to supplement the heating input requirements and in conjunction with windows and light wells provides sufficient daylight to enable much of the installed artificial lighting to be switched off during the day. It is understood that the atrium glazing is designed to reduce heat loss / gain through convection.

The building has a centralised building management system to ensure effective control although some issues have been raised with regard to a number of the control routines related to the operation of the natural ventilation louvers in the central atrium. The system also controls the operation of window blinds to optimise the effects of solar gain during the summer and winter to minimise cooling and heating requirements respectively. Although of low energy design incorporating many low energy features, concerns were raised during the survey that the building can be warm during the summer and cold in the winter months. During the summer months the building uses natural ventilation for cooling with some perimeter office cooling although this is limited to provide a reduction in space temperature of only 4^{o}C less than external space temperatures with a maximum of 32℃ for external temperature to conform local regulations on the use of air conditioning in Geneva.

Cooling is provided through perimeter fan coil units served by an ice bank which is charged at night using low rate electricity. Plans are in place within Geneva to install a district cooling system based on using water from Lake Geneva ("Geneva Lac Nations" project) which will reduce the requirements for cooling via the vapour compression and ice bank system with a considerable reduction in carbon emissions. This project is expected to be functional for UNHCR for 2011 summer.

The basement HVAC systems which serve the perimeter of the office areas to provide heating in the winter and supplement cooling in the summer are designed as a once through system to provide minimum fresh air requirements only (in conjunction with the natural ventilation provided through opening louvers). These HVAC systems incorporate a thermal rotating wheel which is controlled to recover heat from return air in the winter and cooler air in the summer if the exhaust air temperature is lower than ambient air temperatures. Operation is controlled by the building management system.

The building landlord is FIPOI (Fondation des Immeubles pour les Organisations Internationales), a Swiss foundation between the Swiss Confederation and the state of Geneva. The FIPOI completes all basic maintenance costs including preventative, planned and emergency activities. Maintenance was observed to be good although no check was completed to ensure that required maintenance cycles are honoured. The landlord is understood to be responsible for replacement of ageing equipment and has completed, and has plans to complete, a number of changes that will result in a reduction in energy usage .

6.4.4 GHG and Energy Analysis

Based upon an analysis of the MBT building's energy consumption and a mapping of the energy consuming equipment, a total GHG footprint for the building operations of 185 tCO_2e was calculated for 2008. This footprint can be further broken down as shown in **Figure 6.4**.

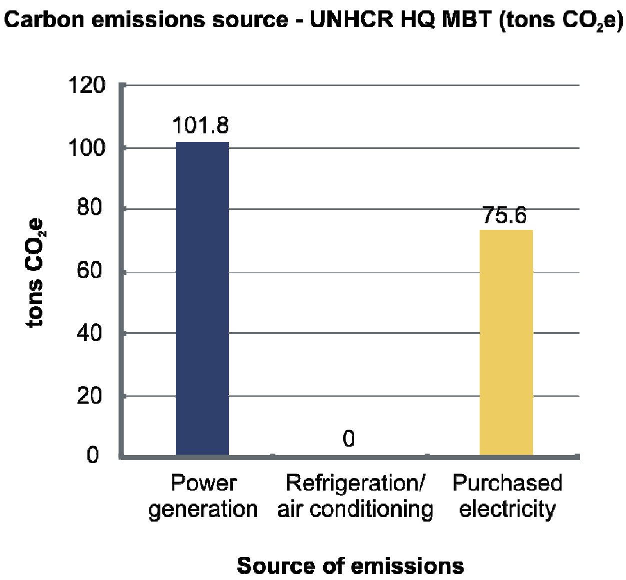


Figure 6.4 GHG Breakdown of the UNHCR Geneva headquarter building

6.4.5 GHG Reduction Opportunities

Through the implementation of the GHG footprinting exercise and the use of the Guide, a number of opportunities have been identified to save energy and therefore reduce GHG emissions as summarised in Table 6.4.

Proposal Idea	Reference Measure	Estimated Capital Cost (US$)	Payback	Tonne CO_2 reduction per annum
Energy efficiency of computers and servers	OFF-04	TBC	Within 1 year	7
Optimisation of natural ventilation controls	-	$7,200	1.3 years	2.4
Improved lighting control	LIG-02	$72,000	3 years	4.6
Kitchen power usage—installation of timers	OPS-03	$4,300	2 years	0.4
Closing of office doors to avoid energy losses	-	$0	Immediate	1.5
Optimise server room cooling by ensuring maximum chiller loading rather than split loading	HVAC-04b and f	TBD	TBD	0.1
Optimise kitchen refrigerators	-	$0	Immediate	0.1
BMS control of boilers especially during in low loadings	HVAC-05c	$TBD	Immediate	1

Table 6.4 Identified GHG reduction measures

6.4.6 Summary

Based upon the identified findings and the use of the Guide, the GHG position of the MBT building is summarised in **Figure 4.5** if all measures were implemented. This represents an approximate 10% reduction in the GHG levels of the building.

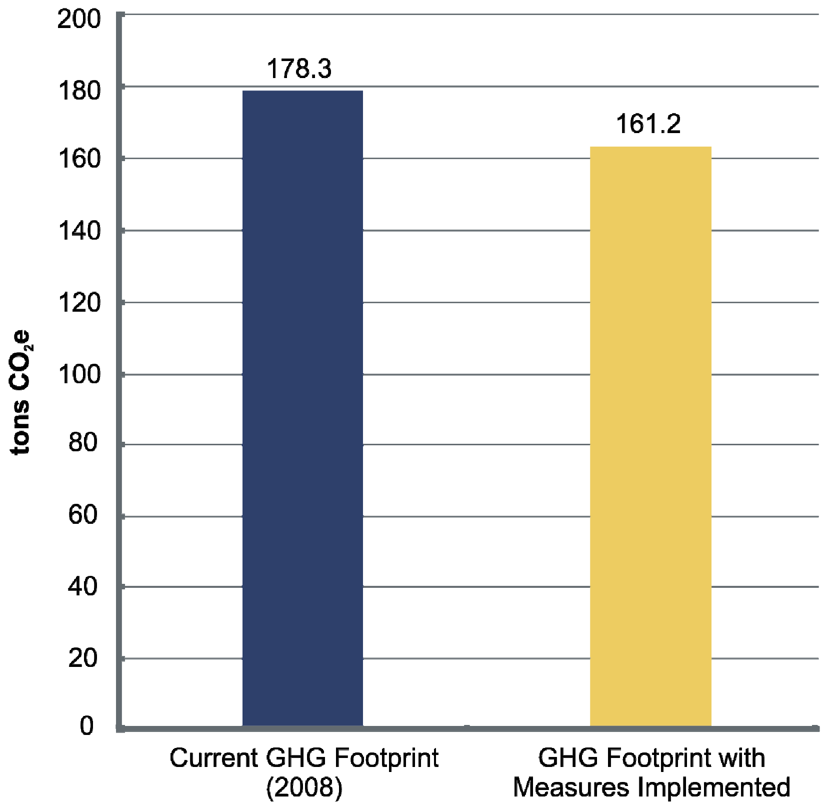
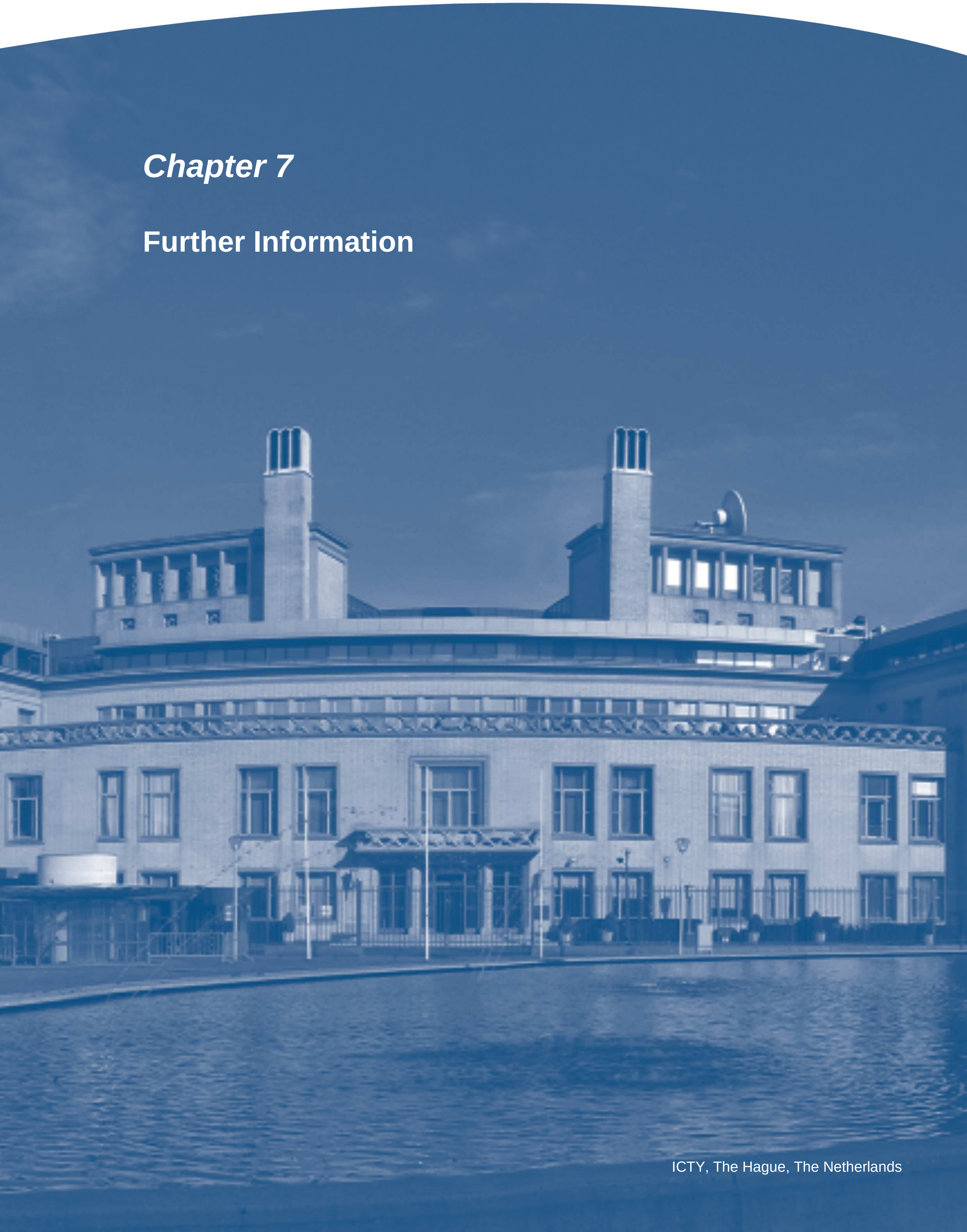


Figure 6.5 GHG emission reduction through implementation of measures

Chapter 7

Further Information



ICTY, The Hague, The Netherlands

7. Further Information

The following websites are available for further information relating to the UN's activities and commitments around climate friendly and sustainability initiatives:

Sustainable United Nations (SUN) Facility

www.unep.fr/scp/sun/facility/
www.unemg.org/sustainableun/
www.greeningtheblue.org (to be launched in June 2010)

Niclas Svenningsen
Head, Sustainable United Nations (SUN)
UNEP Division of Technology, Industry and Economics
15, rue de Milan
75441 Paris Cedex 09, France
Email: sustainable.un@unep.org

UNEP Sustainable Buildings and Climate Initiative (SBCI)

www.unep.org/sbci

Sustainability at the United Nations Environment Programme

www.unep.org/sustainability/

United Nations Inter-Agency Network of Facilities Managers (INFM)

www.un.int/infm/

Annex A: GHG Reduction Measures

Annex A.1: Energy Supply and Distribution (ESD)

The eight measures presented under this section consider four main topics of:

- The lease structure with the landlord and options for pursuing a green lease;
- The provision of both main metering and submetering;
- External energy supply which looks at energy tariffs, green power options and rebate programmes; and
- On-site energy supply including combined cycle energy options and renewable energy solutions.

The individual measures can be summarised as follows:

Reference	Measure
ESD 01	Lease Negotiation
ESD 02	Metering (a) Main Metering (b) Sub-Metering
ESD 03	External Supply: (a) Energy Tariffs (b) Green Power (c) Utility Rebate Programmes
ESD 04	On-Site Supply: (a) Combined Cycle Options (b) Renewable Energy

ESD-01
Lease Negotiation

Benchmarks & Rules Of Thumb

- The larger the office space, and the larger the percentage of a given building occupied, the stronger the negotiating position with the landlord
- Working in collaboration with the building landlord will enable greater GHG reductions compared to working in isolation as a tenant

Introduction

Base building systems typically under landlord control can include chiller/boiler plants, air handling, terminal equipment, lighting, building automation and control. By controlling the base building systems, landlords have an important role to play in the implementation of this Guide and the UN's climate neutral aspirations. The landlord should be made aware of the UN's commitment to a low energy/carbon office and discussions should be held in terms of collaborating to reduce GHG emissions. Consideration should be given to 'green lease' options that promote and create a partnership between the landlord and tenant.

Approach

1. Meet with landlord to review the UN's carbon neutral aspirations and the intent of this Guide.
2. Compile relevant information and data for discussion with the landlord including the current office lease, utility bills of the last 12 – 24 months and any energy audit findings (such as the results of implementing this Guide).
3. With this information, negotiations can be started with the landlord about the existing lease and opportunities for collaborating on energy efficiency and low carbon measures.
4. More information on green leases can be found in Section 4.3 of this Guide.
5. When searching for new offices to lease if moving or opening a new office, specify from the outset that an energy efficient building is a top priority for the UN. Enquire about the energy efficiency measures that have been carried out to the building already and gather historical energy use for comparison. Discuss green lease options with prospective landlords from the beginning.

Benefits

- Working in collaboration with the landlord will enable greater GHG emissions to be achieved.
- Collaboration may also enable cost-sharing on more capital intensive items.
- A green lease is showing a joint commitment to the building in question by both landlord and tenant.

Technical Requirements

- Legal expertise to negotiate the contract.
- Energy efficiency expertise to analyse current consumption profiles and advise on relevant energy and GHG reduction clauses and commitments.

Cost & Payback

- No cost for the actual lease negotiation (legal costs aside). Payback will depend upon the lease agreement but can be immediate.

Risks

- Negotiation could be a time-intensive process and could lead to high legal costs.
- Success will depend on the flexibility of the landlord and the organisation's relationship with them.
- Once in contract, both parties will then be obliged to deliver on the agreed energy efficiency measures.

Further Information

- www.lowcarbonbuildings.org.uk/home/
- www.greenhouse.gov.au/government/publications/eeg.html
- www.greenleases-uk.co.uk
- sustainca.org/context/green_leases_toolkit
- www.environment.gov.au/settlements/government/eego

Linkages

- Broad linkage to many of the measures described depending upon the lease negotiations and contractual agreements with the landlord
- ESD-03b Green Power and ESD 03c Utility Rebate Programmes (may be particularly relevant where collaboration may improve negotiating position)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

ESD-02a
Metering — Main Office Metering

Benchmarks & Rules Of Thumb

- You can't manage what you can't measure
- It is advisable to have direct measurement meters for electricity, gas, oil and other energy consumed by each office
- 1-2% energy savings are possible through increased awareness of energy use

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

For smaller offices and older buildings, energy costs and consumption may be managed and paid for by the landlord, as opposed to the UN as a tenant. This may be due to the absence of a dedicated energy meter and/or due to contractual arrangements. All offices should assess and determine if they have energy bill responsibility and that the supply of energy to their office is metered. By having meter data, it is the first step to understanding consumption patterns and putting in place GHG reduction strategies.

Approach

1. Investigate existing lease arrangements in terms of energy bill payment, and also whether a dedicated energy meter for the UN office exists.
2. Where the energy costs are all directly covered by the landlord, engage with the landlord with a view allowing the UN to be directly responsible for these bills, and where no meters exists, engage with the landlord to get appropriate main metering installed. Either scenario may mean the lease may need to be renegotiated.
3. Where new metering is needed, or existing meters can be replaced, consider smart meters, which allow consumption to be measured automatically and at different times of the day.
4. For UN offices that do receive and pay their own energy bills, find out from the landlord whether these bills include for the provision of heated/cooled air. For many office buildings, this item is not covered by tenancy metering and in typically under the landlord's control.
5. If heated/cooled air is not separately metered, discuss with the landlord how this data specific to the UN office's consumption may be generated or extrapolated.

Benefits

- Meters will enable offices to quantify energy consumption and therefore their associated GHG emissions, and motivate energy efficiently.

Technical Requirements

- Expertise to install the meters.
- Legal advice if the existing lease conditions need to be changed.

Cost & Payback

- Individual meters can vary in price depending upon complexity and type.
- The approach may result in cost savings where the landlord currently pays the energy bills (typically involving a handling and processing charge).
- In terms of GHG management, once the UN office understands their consumption trends, they are better placed to manage and reduce the costs.

Risks

- Existing lease conditions and/or landlord stance may not make this possible.

Further Information

- www.energysmart.com.au/sedatoolbox/pdf/monitoring_energy.pdf
- www-03.ibm.com/industries/utilities/us/detail/solution/M874508U48403V13.html
- www.usgbc.org/
- www.epa.gov/energystar

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- ESD-02b Sub-metering (additional metering enables a better understanding of energy consumption profiles and needs)
- This measure is a key starting point for all other measures as it will enable baseline quantification and on-going monitoring of energy and hence GHG emissions

ESD-02b
Metering — Sub-metering

Benchmarks & Rules Of Thumb

- Provision for sub-metering should be considered if gross floor area of the organisation's office is more than 500 m^2
- You can't manage what you can't measure
- Separate metering should be applied to areas that use 100kVa or more of electricity/ power

Introduction

The installation of sub-meters in addition to the main tenancy meter (ESD 04a) can allow specific energy consumption of individual systems (e.g. lighting, cooling, heating etc) or individual task or activity areas (e.g. data centres, 24 hour uses) to be quantified, and so allow targeted action to be taken to reduce any higher than expected figures.

Approach

1. An office energy audit and feasibility study should be undertaken before a metering system is designed to identify the main priority areas for installing meters. This will allow the compilation of key energy consuming systems and items.
2. Preliminary energy data may be obtained if necessary to support the activities in point 1 above through the use of hand-held portable instruments.
3. Once key energy consuming systems and areas have been identified, an energy sub-metering plan should be developed. The local utility company or an energy consultant could be used to support in this.
4. The more frequent the meter measures and collects data, the better the analysis of the data, therefore smart energy meters with on-board data logging capability, which are automated and can measure at different times of the day, should be considered.
5. Typical office features to be considered for sub-metering include individual floors, as well as the heating/cooling system, lighting, IT and data centre rooms and hot water heating systems.

Benefits

- Installation of sub-meters allows energy usage and GHG emission trends within the office to be better understood and therefore develop management plans accordingly.

Technical Requirements

- Expertise to determine the sub-metering pattern and subsequent installation.
- Technical know-how to analyse data from sub-meters, model the load demand profile and reduce where over-consumption is identified.

Cost & Payback

- There will be both initial costs (i.e. purchase and installation) and on-going operations costs (e.g. data analysis, system maintenance, and resulting corrective actions).
- Payback varies as it will depend on the energy savings generated from any identifiable opportunities resulting from the meter data analyses. It is often shown that savings identified have paid for meter installations in a matter of months.

Risks

- The success of advanced metering technologies is the availability of staff that are motivated and trained to use the data, analyse it and implement energy reduction strategies and processes.

Further Information

- www.energysmart.com.au/sedatoolbox/pdf/monitoring_energy.pdf
- www-03.ibm.com/industries/utilities/us/detail/solution/M874508U48403V13.html
- www.usgbc.org
- www.epa.gov/energystar

Linkages

- ESD-02a Main Tenancy Metering (main metering must be in place first)
- Sub-metering will then link to a large number of the other measures in that it ensures a better data set and understanding of the energy consumption patterns across the office's equipment, systems and activities

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

ESD-03a
External Supply — Energy Tariffs

Benchmarks & Rules Of Thumb

- Applicable in deregulated energy markets, and where the office is mains grid connected
- Depending upon current contract structure, cost savings of 10% or more may be achievable
- The greater the consumption, the more appropriate this measure is. If off-peak and night-time energy consumption exceeds 15% of total use, this measure should be pursued

Introduction

This measure applies only to deregulated energy markets and focuses on assessing and obtaining the best value tariff structure for electricity, gas, steam and other energy utilities. Off-peak energy use should be a prime determining factor. Whilst this measure itself does not allow for GHG emission reductions, by reducing the overall price of energy, it may make other options (such as Green Power – ESD-03b) more attractive or viable. For existing contracts, procedures and responsibility should be put in place to ensure that the contract is tendered prior to the expiry of current supply to avoid the potential of entering a default cost tariff which can often result in an increase in electricity costs.

Approach

1. Determine if this measure is applicable by researching the local energy markets to determine if they are deregulated.
2. Compile energy bills for a minimum of the prior two years for benchmarking purposes.
3. Determine from bills or existing supplier the night-time and off-peak consumption, and peak level consumption. If this information is not readily available, take meter readings at the end of the day and first thing the following morning to determine the night-time consumption.
4. Assess forecasts of energy consumption and costs for the coming year using benchmarking data.
5. Obtain quotes from existing and competitor energy suppliers - this can be done quickly by consulting price comparison sites, or going to the websites of alternative energy suppliers. Energy consultants can also be engaged to support if appropriate.
6. If a cheaper deal can be found elsewhere, switch supplier as soon as possible subject to existing contractual obligations. Existing contracts can often only be finished early with the payment of a penalty charge and this needs taking into consideration.

Benefits

- Reduces energy spending at zero cost.

Technical Requirements

- Good analytical skills to compare tariff structures and costs offered by competitive quotations. There are companies who offer these services, but consideration of their use is recommended only for offices and buildings with complex consumption patterns.

Cost & Payback

- Zero cost, therefore immediate payback if a better price can be found (subject to confirming that there is no financial penalty if tied into an existing contracted supply).

Risks

- Ensure that for potential suppliers, all terms and conditions are fully reviewed including the potential for 'hidden costs' such as metering fees, load variance penalties and loss factors.
- Over time, the selected supplier may become more expensive than the previous supplier. In that event it might not be possible to switch back, depending on the contract signed.

Further Information

- www.energyshop.com/
- www.uswitch.com/gas-electricity/ppc/energy-comparison/?gclid=CMftol_1u5kCFQulQwodGWko6g

Linkages

- ESD-03b Green Power (combining supplier assessment with green power options)
- OPS-03 Equipment Start-up (could be influenced by the known energy tariffs for peak and off-peak times)
- HVAC-02 Controls (linkage of energy tariffs to building operating controls)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

ESD-03b
External Supply — Green Power

Benchmarks & Rules Of Thumb

- Applicable in deregulated energy markets, and where office is mains grid connected
- Green power can sometimes accrue a 10-30% cost premium
- Green power represents the easiest way to achieve GHG reductions, however it should not be a justification for 'business as usual', and should be supplemented by a parallel energy management programme

Introduction

In deregulated markets, electricity is supplied through various generation sites and connected to a centralised grid. As a customer in markets where green power options exist, choosing green power means that the energy provider buys more energy from renewable sources on the customer's behalf. Therefore the selection of green power (also known as green electricity or green certificates) offers viable GHG reductions, and does not necessarily require a change of provider. In many instances, it can be the quickest and easiest way to achieve GHG reductions, however it is recommended that green power should not be a justification approach for 'business as usual', and a parallel energy efficiency and management programme should be implemented. Using green power as an emission reduction strategy will significantly reduce GHG emissions but will not capture cost savings of reduced energy consumption.

Approach

1. Determine if this measure is applicable by researching the local energy markets to determine if they are deregulated and energy providers offer green power options.
2. Compile energy bills for the last two years and generate energy consumption figures.
3. Assess forecasts of energy consumption and costs for the coming year.
4. Select the amount of green power to be purchased (as a percentage of total consumption), and if important to the UN organisation, select the energy source of preference (e.g. wind, solar etc).
5. Research green power providers and ensure their credibility and robustness can be verified.
6. Obtain quotations for green power options, and select green power provider.

Benefits

- Allows GHG reductions commensurate with the percentage green power purchased e.g. 100% green power effectively means carbon offsetting of electricity usage.

Technical Requirements

- Good analytical skills are required to accurately analyse cost and usage comparisons.

Cost & Payback

- Green power typically (although not always) has a cost premium compared to conventional energy costs. No payback will occur.

Risks

- Increased costs (typically 10-30%) for green power purchased, but these could potentially be offset by combining with measure ESD-03a Energy Tariffs or through other Government initiatives to utilise green power.
- Ensuring that sufficient due diligence is undertaken of green power providers and their stated sources of green power, to ensure it is credible and verifiable.
- As a means to reduce GHG emissions, green power should be viewed as the final option after consumption reduction and energy efficiency.

Further Information

- www.greenpower.gov.au
- www.epa.gov/grnpower
- www.green-e.org/
- www.eere.energy.gov/greenpower
- www.thegreenpowergroup.org/eu

Linkages

- ESD-03a Energy Tariffs (opportunity to combine supplier assessment with tariff options for peak and off-peak times)
- ESD-01 Lease Negotiation (may be possible to combine power purchases with those with the landlord for the base building and therefore getting a better rate)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
X	>10%

ESD-03c
External Supply — Utility Rebate Programmes

Benchmarks & Rules Of Thumb

- Rebate opportunities may make the investment in GHG reduction projects viable
- To find out what incentives are available, contact the local energy and utility providers, as well as Government departments

Introduction

This measure requires the office to consider opportunities for obtaining rebates from Government, regions or utility companies that may be available through investing in energy efficient technologies or renewable systems. These rebate opportunities may make the investment in GHG reduction projects viable.

Approach

1. Research of local Government, regional/federal and utility supplier programmes and eligibility of the UN organisation. To find out what incentives are available, contact the local energy and utility providers, as well as Government departments.
2. The types of programmes that could be considered include:
   - Investment subsidies: the authorities refund part of the cost of installation of the system.
   - Feed-in tariffs/net metering: the electricity utility buys electricity from the producer (assuming the office has an on-site energy source) under a multiyear contract at a guaranteed rate.
   - Renewable Energy Certificates (RECs): a green energy provider is credited with one REC for every 1,000 kWh or 1 MWh of electricity it produces.
   - Smart meters: an economical way of measuring this information, allowing price setting agencies to introduce different prices for consumption based on the time of day and the season.
3. If a suitable scheme is identified, and the eligibility of the UN is confirmed, make a relevant application.

Benefits

- Investment subsidies would allow the UN to invest in more high-profile albeit costly measures.

Technical Requirements

- Varies depending upon rebates that may be available and the obligations for securing these rebates.

Cost & Payback

- To research and submit an application will mainly cost staff time, so costs are low but it may result in subsidies that benefit the UN office.

Risks

- UN may not be eligible for the rebate programs as they may be targeted at households or small business, or internal UN rules may prevent participation.

Further Information

- apps3.eere.energy.gov/greenpower/markets/certificates.shtml?page=1
- www.dsireusa.org/searchby/SearchTechnology.cfm?EE=0&RE=1
- www.energysavingtrust.org.uk/
- www.cansia.ca/Default.aspx?pageId=139888

Linkages

- There is potential linkage to nearly all the measures described as the specific utility rebate programmes may be general (i.e. refer in general terms to energy efficiency) or may be specific (focusing on a specific technology such as solar water heaters)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

ESD-04a
On-Site Energy Supply — Co-generation

Benchmarks & Rules Of Thumb

- Co-generation plants are less carbon intensive for every unit of electricity produced
- Co-generation on average reaches 85% efficiency compared to around 50% for modern electricity plants

Introduction

Many buildings have stand-by generators (diesel-powered) which can be used to supplement power supplies and reduce peak loading. However using diesel generators (which operate as a simple cycle) in isolation as a power supply is about 35% efficient (or less) and is therefore not advantageous in terms of GHG emissions. If a co-generation is considered where heat is recovered and recycled by heating hot water, (or even trigeneration where steam is generated for absorption cooling), the increased fuel utilisation efficiency can present significant increases in overall efficiencies and reductions in cost and GHG emissions.

Approach

1. Evaluate the current generator together with fuel availability for potential for conversion or need for full replacement. Then establish demand and energy use profile and model the generator hour fuel and maintenance costs for running existing generators.
2. Determine constraints that may exist relating to the longer use of equipment such as duty cycle, the need for parallel switching, the lack of ventilation or noise impacts.
3. Determine detailed electricity consumption, electricity rate tariff and actual cost for the past two years, including peak and off-peak usage and power factor, and whether incentives are available from the local utility company.
4. Analyse and model the demand patterns to quantify the electricity and heat that will be supplied by co-generation cycle and the amount that will require topping up from grid power or other sources.
5. Develop the co-generation cycle business case.

Benefits

- With incentives, the cost of energy especially during peak hours might be lower than the utility power.
- Co-generation plants are less carbon intensive for every unit of electricity produced.
- Co-generation plants are well suited to operate at peak and intermittent power demands and can be switched off at night when electrical costs are low.

Technical Requirements

- Expertise to analyse and perform energy modelling.
- Technical know-how to analyse the business case and perform cost-benefit analysis of the conversion.
- Expertise to install, operate and maintain given the longer expected hours of operation.

Cost & Payback

- This will depend on the type and cost of the fuel used and the cost of conversion to co-generation.

Risks

- The fuel used such as natural gas or diesel is dependent on global price fluctuations and volatility.
- The UN may not be eligible (internal or external rules) for any peak sharing utility incentive programs.
- Ensure longer term operation of standby generators will not result in premature failure of the engine. Redundancy must be designed into the program.
- Ensuring suitable provision for training, repair and maintenance.

Further Information

- soapp.epri.com/papers/CC_Heat_Recovery.pdf
- www.cogeneration.net/Combined_Cycle_Plants.htm
- www.leonardo-energy.org/webfm_send/1221

Linkages

- ESD-03a Energy Tariffs (important for determining the cost-effectiveness of conversion)
- ESD-04b Renewable Energy (combine energy sources)
- HVAC-06 Boilers and Hot Water (possible replacement of existing hot water systems)
- ESD-03c Utility Rebate Programmes (may make investment more viable)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
X	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
X	>10%

ESD-04b
On-Site Energy Supply — Renewable Energy

Benchmarks & Rules Of Thumb

- Investigate energy efficiency measures first to reduce consumption and demand then follow with renewable energy generation
- If the office has a large hot water consumption, consider converting to solar hot water
- Solar water heaters can reduce water heating bills between 50%–80%

Introduction

Renewable energy options will exist where UN offices have roof and additional space access to install renewable energy systems such as solar hot water. Other options do exist such as photo-voltaic (PV) panels and wind turbines, however these options tend to have a long payback period which often makes them unaffordable for buildings. Typically PV and wind turbines can only be justified if there were additional incentives such as the availability of grants (see ESD-03c). It is rare for renewable energy options to power a whole building, rather they can act as a supplementary energy source.

Approach

1. Indentify availability of space (e.g. roof areas) for potential renewables and determine whether any structural upgrades may be needed to support the renewables, as well as potential lease constraints.
2. Research the office's climatic position and the weather profiles such as sun and wind that may support consideration of renewable energy options.
3. Compile an inventory of energy loads for the office and current and historical electricity demand profiles, or hot water needs.
4. Research of regional/national incentive or rebate programs for renewable energy generation on site.
5. Research of renewable energy retailers and any leasing programs offered.
6. Identify potential suppliers and develop business case model for installation.

Benefits

- Decrease dependency on fossil fuel based resources and hence decrease of GHG emissions.
- If funding incentives are available, the cost of renewable energy can be lowered and be more attractive.

Technical Requirements

- Expertise to analyse and perform energy modelling and understand the energy options that renewables would bring if sited at the office.
- Technical know-how to analyse the business case and perform cost-benefit analysis.

Cost & Payback

- Solar water heaters can cost anything from $500 to $1,200. On average, solar water heaters can reduce water heating bills by between 50%–80%, hence the payback will vary.
- Solar electricity generated from PV can cost between $6,000 - $10,000 per kW (capital investment), or $0.20 and $0.40 per kWh for generated power.
- Paybacks for renewables such as PV and wind of 20-30 years are common, which incentives may reduce.
- Leasing may present a better option where up-front costs are covered by the leasing organisation.

Risks

- The often large payback periods often make this approach unattractive.
- Energy generation from renewables can be unpredictable and generate less than predicted.

Further Information

- www.dsireusa.org/
- www.solarbuzz.com/DistributedGeneration.htm
- apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12860
- www.energystar.gov/index.cfm?c=healthcare.bus_healthcare_onsite_energy

Linkages

- ESD-03a Energy Tariffs (renewable energy may help reduce peak loads)
- ESD-03c Utility Rebate Programmes (opportunity may exist to partially fund renewable energy approaches)
- OPS-03a Minimise Start-Up Load Peaking (opportunity to reduce the peaking)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Local climate can influence options e.g. sun or wind availability	

Capital Cost (US$)	
	No cost
	$0 - 10k
	$10k - 100k
X	$100k - 500k
X	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
X	>10%

Annex A.2: Operations and Behaviour (OPS)

The five measures presented under this section consider three main topics of:

- Understanding energy bills;
- Challenging the office thermal comfort settings such as temperatures; and
- Equipment start up and operation, both in terms of minimising start-up load peaking, and also for general operation times.

With respect to behaviour, the focus of this Guide is on the activities and actions facility and building managers can have, rather than the behaviour of office and building users.

The individual measures can be summarised as follows:

Reference	Measure
OPS 01	Understanding Energy Bills
OPS 02	Thermal Comfort Settings
OPS 03	Equipment Start-Up (a) Equipment Operation Times (b) Minimise Start-Up Peak Loading

OPS-01
Understanding Energy Bills

Benchmarks & Rules Of Thumb

- Billing errors can arise for a number of reasons such as incorrect meter readings, clerical errors, incorrect billing calculations or the use of incorrect tariffs
- Understanding and scrutinising bills can identify immediate cost savings and help in understanding an office's energy consumption patterns

Introduction

Meter readings can be estimated or sometimes based on inaccurately read figures, which can result in the office being billed for energy which it has not used. Checking billed information against actual meter readings can ensure potential discrepancies can be identified leading to instant costs savings and improved cost accounting. Whilst not a direct GHG saving measure, ensuring that the energy billing is correct can identify potential cost savings which can then be utilised on other GHG reduction measures.

Approach

1. Ensure that the office has an energy meter in place and the UN is paying its own energy bills directly (see ESD-02a).
2. Begin taking actual meter readings for the office manually on at least a monthly basis.
3. Clarify the energy tariffs that apply to the office (see ESD-03a).
4. Compare the manually recorded meter readings to the actual bills and check for accuracy and errors.
5. It is recommended that an employee is designated to be the custodian of all energy data and to take meter readings for comparison with invoices.

Benefits

- Meter readings will enable energy reconciliation between the utility bills and clarify any discrepancies if needed.
- Identification of potential errors and therefore potential over-billing.

Technical Requirements

- An understanding of electricity tariff structures and bills.
- Technical know-how to read the data from the electric meters. This is important especially regarding energy (kWh) data and power consumption data (kW) integrated over periodic intervals of 15 minute, ½ hour or an hour.

Cost & Payback

- This is a no-cost item beyond the time to read the meters and compare with the energy bills.
- As mentioned above, if the utility reimburses for any error made with regards to metering data on their side, then the payback is immediate.

Risks

- None identified.

Further Information

- apps1.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12750
- www.pickocc.org/publications/electric/Electric_Meter_Reading.pdf
- apps1.eere.energy.gov/consumer/your_home/electricity/index.cfm/mytopic=11150

Linkages

- ESD-03a Energy Tariffs (understanding tariff structure can ensure bills are better understood)
- ESD-02a Main Metering (this measure is only relevant if the office has a main meter and the bills are paid directly by the UN)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

OPS-02
Thermal Comfort Settings

Benchmarks & Rules Of Thumb

- A 1°C reduction in space heating or increase in the air conditioned temperature can result in a 10-15% reduction in energy consumption
- Acceptable summer temperature ranges are 22—26°C, and winter temperature ranges are 18—22°C
- Optimum humidity levels should be between 40—60%

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

Occupant satisfaction with indoor thermal comfort levels is often much lower than expected, with many offices overheated or too cold. Finding the optimal temperature settings will help save energy and improve occupant comfort. The optimal temperatures will depend upon a number of factors such as occupant activity levels, air movement and humidity. The office space temperatures can have a significant impact on energy consumption, which can be further affected when adjacent areas have different temperature settings. Challenging and seeking fixed maximum space heating temperatures and minimum cooling temperatures can achieve a significant energy reduction while maintaining a comfortable working environment.

Approach

1. Confirm that the thermostats are working (see HVAC-01a) and that the set temperature (that set on the thermostat) and the ambient temperature (actual room temperature) are within 2-3 °C.
2. Establish minimum agreed cooling temperatures and maximum space heating temperatures (see Rules of Thumb above). Local or international best practice standards could be used to help determine these levels e.g. ASHRAE standards.
3. Once the acceptable temperature ranges are established, ensure that the office controls and performance can meet these standards.
4. Ensure that a suitable ‘dead band’ of around 3°C is in place between systems operating in heating and then cooling mode to allow for opportunities for free air cooling (OPS-03c).
5. Where individual zone or room thermostats are present, ensure that they are set to the same temperatures to prevent simultaneous heating and cooling in adjacent rooms.
6. Ensure any changes to current operating practices are implemented slowly e.g. 0.5 °C at a time, to ensure occupant satisfaction.

Benefits

- Reduced heating and air conditioning energy usage.
- Reduced loading and operating hours of heating and air conditioning plant which can result in an increased equipment life.
- Occupant satisfaction from more acceptable office conditions.

Technical Requirements

- Ability to set and adjust existing heating and air conditioning temperature controls.
- Some re-commissioning of temperature sensors may be required (and associated control valves) to ensure that accurate space temperature control is achieved.

Cost & Payback

- The cost of adjusting existing controls is minimal.
- If re-commissioning of temperature sensors and valves is required then some cost will be incurred although this should be relatively low.

Risks

- Agreement is required by all staff to set points and for implementation by maintenance staff with spot checks to ensure compliance.

Further Information

- www.wbdg.org/design/provide_comfort.php

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
X	>10%

Linkages

- HVAC-01a Thermostats (need to ensure the thermostats are fully operational and capable of performing)
- HVAC-03 Air Economiser / Free Cooling (opportunities to allow free cooling can help maintain desirable temperature ranges)

OPS-03a
Equipment Start-Up — Minimise Load Peaking

Benchmarks & Rules Of Thumb

- Reducing the peak load, which typically coincides with the highest general energy demands, will enable potential cost savings
- Apply this measure during high consumption periods such as 7-9 am and 4-6 pm during working week days, especially in locations with distinct Summer and Winter months (coinciding with domestic increased demand)

Introduction

Turning on all plant and equipment on at the same time, which is typical when an office starts up in the morning, can result in high maximum demand spikes which can affect tariff costs. Staged switch on of main items of equipment can ensure that maximum demand charges can sometimes be reduced. Whilst not a GHG reduction measure in its own right, when combined with OPS-03b, GHG reductions can be achieved whilst also saving on energy costs.

Approach

1. Compile a list of the start-up procedures and equipment, and assess the starting currents.
2. Obtain a copy of the tariff structure applicable to the office in order to recognise the peak and off-peak times and associated costs (ESD-03a).
3. Stagger the start up schedule of equipment with large starting currents such as air conditioning, electric space heating and master lighting. If a building management system is available, utilise this to schedule the start ups.
4. Reduce the use of master lighting during peak energy demand hours, as these peak hours normally occur when daylight can be most effectively utilised.
5. Investigate the potential for shedding other loads during peak demand hours and shift it to off-peak hours if needed (ESD-04a).
6. Install alarms/triggers to notify when the current demand is close to maximum demand.
7. An option may be to stagger shifts or using flexible work schedules to empty offices during energy peaks.

Benefits

- If the energy tariff structure is based on the time-of-use, then staggering the start up of equipment during off peak hours can reduce peak energy consumption, resulting in energy cost savings.
- Reduces the risks of sudden peak load conditions causing voltage and variations that are harmful to other loads.

Technical Requirements

- Expertise to modify building management system settings and/or install time switches.
- Technical know-how to co-ordinate and maintain the start-up of the equipment. All access to electrical panels and controls should be by certified electrical technicians.

Cost & Payback

- Both cost and payback will vary. The payback will depend on the savings achieved through the respective tariff structure, as well as the impact of the shut downs on the life span of the equipment.

Risks

- Numerous start-ups and shut-downs of equipment can be detrimental and might decrease the life span.
- Incorrect sequencing of equipment start-up against the occupant patterns may lead to complaints.

Further Information

- oee.nrcan.gc.ca/publications/infosource/pub/cipec/efficiency/2_04.cfm?attr=20
- bge.apogee.net/ces/library/business_10.asp

Linkages

- ESD-03a Energy Tariffs (understanding tariff structure can focus on when to reduce peak loads)
- ESD-04b Combined Cycle Options (opportunity to reduce peak loads through use of on-site power)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

OPS-03b
Equipment Start-Up — Equipment Operation Times

Benchmarks & Rules Of Thumb

- Challenge the existing start-up timings and link to occupancy patterns
- For every hour that the HVAC system operation time is reduced, associated HVAC energy consumption is reduced by between 5 and 10%
- An extra hour overrun of equipment usage on a typical 8 hour day can increase energy consumption of that equipment by up to 10%

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

For many offices and buildings, the start-up process is often routine and consistent, especially when manually undertaken, irrespective of the occupancy patterns or outside weather conditions. The start-up and switch-off times of major systems should be challenged to optimise performance and minimise operating times, and hence reduce energy and GHG emissions. The aim is to match the supply of cooling, heating and lighting to the occupancy demand patterns.

Approach

1. Compile an office use profile to understand when occupants start and finish, as well as different shifts and out-of-hours activities.
2. Assess and review seasonal climatic conditions and how this will affect cooling, heating and lighting needs.
3. With this information, a schedule can be established with daily, weekly, weekend and holiday operating times. This schedule should challenge the current equipment operating times.
4. Once this has been established, it may then also be possible to adjust the schedule and further refine on and off times. For example the refinement could be based on assessing at the end of the day the timing for turning off the heating/cooling system but allowing the fans to continue operating to see how long it takes to become uncomfortable for occupants.
5. Consider using after-hours manual override, where after-hours work is sometimes required.
6. Challenge the operating hours in conjunction with the operating temperatures through the use of thermostat controls (see OPS-02).
7. Consider free cooling in order to take advantage of external temperatures (see HVAC-03).

Benefits

- Allows GHG reductions to be achieved through reduced operating times of equipment and hence reduced energy consumption.

Technical Requirements

- Nothing specific as in general it will rely on refinement of the existing approaches.
- If a BMS is being used, technical support may be need for reprogramming the operating schedules.

Cost & Payback

- No costs will be incurred other than the time taken to analyse the start-up times, and the payback in terms of reduced energy consumption will be immediate.

Risks

- If this is undertaken too aggressively, or too many changes are made at once, it may become too uncomfortable for occupants, therefore it needs to be a gradual process of implementing the new operating schedule.

Further Information

- None identified.

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

Linkages

- ESD-03a Energy Tariffs (understanding tariff structure can focus on reducing peak loads)
- HVAC-03 Air Economiser / Free Cooling (applying the off-peak cooling approaches will impact on the start-up times)
- OPS-02 Thermal Comfort Settings (ensuring thermostat ranges have been suitably set)

Annex A.3: Lighting (LIG)

The nine measures presented under this section fall under the following main topics:

- Ensuring that the correct lighting levels are being used through reducing excessive lighting and enhancing reflectance;
- Lighting controls;
- Maximising daylighting into office spaces;
- Lighting upgrades including for fluorescent lamps, ballasts, emergency signs and down-lighting; and
- Exterior lighting.

The individual measures can be summarised as follows:

Reference	Measure
LIG 01	Lighting Levels (a) Reflectance (b) Reduce Excessive Lighting
LIG 02	Lighting Controls
LIG 03	Daylighting
LIG 04	Lighting Upgrades (a) Lamps (b) Ballasts (c) Emergency Lighting (d) Down-Lighting
LIG 05	Exterior Lighting

LIG-01a
Lighting Levels — Reflectance

Benchmarks & Rules Of Thumb

- Regular implementation of light fixture cleaning improves reflectivity and can reduce light loss by up to 15-20%
- Maintaining room reflectance can further reduce light loss by an additional 10%

Introduction

When lighting fittings are allowed to become dirty, lighting efficiency can drop considerably resulting in reduced light levels, therefore the implementation of basic cleaning regimes will improve light levels. This measure on its own is not a specific GHG reduction measure, however by improving lighting levels, it may allow the number of fittings to be reduced (see LIG 01b) resulting in a subsequent reduction in power consumption and GHG emissions.

Approach

1. Obtain specification documents for the existing light fixtures from the manufacturer or supplier, and before cleaning the light fixtures, consult the manufacturer's data sheet.
2. Establish a good maintenance and cleaning schedule for the lighting system and implement before undertaking any of the other lighting measures described in LIG-01b to LIG-04.
3. The cleaning regime should comprise frequent dusting and regular fixture cleaning by removing the bulbs from their fixtures and wiping using a lint-free cloth. Tubes and fittings should be handled with care as they can be quite brittle.
4. Replace darkened light fixture diffusers and old yellow fittings, which waste a large fraction of lighting energy, with reflector (mirrored) fittings.
5. When replacing lamps, select lamps that do not collect dirt rapidly and can be cleaned easily.
6. To further maximise light distribution, consideration should also be given to painting walls in light colours to maximise reflectance.

Benefits

- Cleaning light bulbs, glass shades, lenses and reflectors will maximise the efficiency of the lights and therefore improve lighting levels.
- Increasing the quality of light may also improve occupant satisfaction.

Technical Requirements

- Train the cleaning staff to clean the shades, reflectors and bulbs without damaging the lamps and wetting the socket ends.

Cost & Payback

- Zero cost and payback.

Risks

- Risk of damaging lamps during cleaning resulting in the need for lamp replacement.
- Careful handling of lamps when being removed for cleaning in case they break.
- Safety risk assessment required to prevent falls from ladders while cleaning fittings.

Further Information

- www.cor.state.pa.us/boa/lib/boa/ScheduleLFacility_MaintenanceChecklist.pdf

Linkages

- LIG-01b Reduce Excessive Lighting Levels (to optimise lighting levels from existing lighting)
- LIG-02 Lighting Controls (linkage to reducing lighting levels)
- LIG-03 Daylighting (linkage to making maximum use of daylight)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
X	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
	>10%

LIG-01b
Lighting Levels — Reduce Excessive Lighting

Benchmarks & Rules Of Thumb

- Offices are typically 30-50% brighter than they need to be
- Typical target lighting levels should be on average 300-500 lux for office areas, around 100 lux for corridors, and about 20-50 lux for non-working interiors
- Health and safety requirements should not be compromised in striving for these optimised lighting levels

Introduction

Office lighting is often at illumination levels far higher than necessary considering the tasks being undertaken, the availability of daylighting and the variation in occupation patterns. In particular, tenants often do not adjust existing lighting to suit their layout and needs. Lighting power usage can be between 20 and 50% of an office's power usage and selective removal of light fittings and provision of desk task lighting to reduce light levels to those required for effective usage of an area will improve energy usage.

Approach

1. Prepare a summary of occupancy by area of the office and lighting expectations. This is important as lighting should be task-focussed. A uniformly lit room may not be appropriately lit for individual tasks being performed within. If necessary, research the required levels of illumination required per task, area and occupancy level.
2. In parallel, prepare an inventory of the number and type of current lighting fixtures per room/area (include details on the type of lamps, ballasts and wiring configurations). Also determine the associated lighting levels (using a light meter) to identify areas which are over-illuminated.
3. Develop a reduced lighting plan focussing on removing unnecessary light fittings in over-illuminated areas such as near windows or where minimal light is needed such as non-critical or non-occupied areas. Fluorescent bulbs should always be removed in pairs. In four-tube fixtures, remove either the outer pair or the inner pair. If all the tubes are removed from one fluorescent fixture, disconnect the ballast as well because, if switched on, it will continue to use electricity even if the sockets are empty.
4. Where necessary, consider lowering background lighting levels and providing local task lighting as required for individual desks. Task lighting has the benefit of only being used when the occupant is in the office, and that large areas do not need to be illuminated.

Benefits

- A reduction in the lighting load will reduce direct lighting energy consumption, and also the cascade effect of reducing cooling requirements.
- Reduced number of lighting fixtures will also mean lower maintenance requirements.
- Creating more task-focussed lighting levels can improve occupant comfort and satisfaction.

Technical Requirements

- Expertise to remove lamps especially in series-wired configurations.
- Technical know-how to use light measurement device.

Cost & Payback

- Removing lamps will have a zero cost and if de-lamping is significant this will lead to a reduction in electricity consumption. The energy cost savings achieved will depend on the tariff structure and price.

Risks

- Ensure that light levels for health and safety purposes are not compromised.
- Removing lights / tubes is more complicated for series-wired configurations.

Further Information

- www.resourcesmart.vic.gov.au/documents/school_lighting.pdf
- www.facilities.ufl.edu/cp/pdf/Lighting%20Illumination%20levels.pdf
- www.unep.fr/scp/sun/publications

Linkages

- LIG-01a Reflectance (to maximise luminance from existing lighting)
- LIG-04 Lighting Upgrades (linkage to improved lighting efficiency)
- LIG-02 Lighting Controls (linkage to reducing luminance levels
- LIG-03 Daylighting (linkage to making maximum use of daylight)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

LIG-02
Lighting Controls

Benchmarks & Rules Of Thumb

- Use of occupancy sensors can save up to 20% of lighting costs
- Research suggests that occupants use up to 40% less lighting when given access to convenient lighting controls

Introduction

Lighting can remain switched on in parts of the offices for long periods even when the areas are not occupied or benefit from good daylight. Installing automatic controls can impact significantly by reducing lighting power usage. The type of control should be based on lighting usage patterns and the type of space served. See LIG-03 for further discussions on daylighting.

Approach

1. Compile an inventory of current methods of lighting control including master switches, rocker switches, dimmer switches, timers etc, and understand current lighting circuits.
2. Compile data on light usage per room based upon average occupancy, activities performed and the timings of occupancy (overlaps with requirements of LIG-01b). This information should be used for lighting zoning patterns which will then form the basis for the installation of sensors.
3. Determine the form of lighting switch to be used for different zones such as occupancy sensors for areas of intermittent occupancy, timer switches for open plan offices, daylight sensors for day lit areas (see LIG-03) and push button switches for intermittent use areas. Note that some types of lighting are not well suited to controls e.g. occupancy sensors with HID (high intensity discharge) lighting.
4. Timer switches are particularly effective in shared open plan spaces where it is difficult to assign individual responsibilities for switching off lights.

Benefits

- Ensures that lighting will be switched off when it is not needed and therefore save on energy and reduce GHG emissions.
- Reduced lighting energy will also mean reduced cooling requirements.

Technical Requirements

- Expertise to install the switches and associated wiring.
- Understanding of lighting levels and requirements to help determine the lighting zoning and switch patterns.

Cost & Payback

- Individual controls on lighting systems can cost on average between $500 to $1,000 to install and typically pay for themselves in under 12 months.

Risks

- Incorrect installation may lead to malfunction.
- Improperly selected and applied lighting control systems may turn lights off while employees still working but not moving enough to activate the sensors.
- The upgrading of lighting controls should also be linked to a behavioural management programme to ensure the controls are properly and effectively used.
- Health and safety must not be compromised when changing lighting controls.

Further Information

- www.efficientlighting.net
- www1.eere.energy.gov/femp/pdfs/light-controls.pdf
- www.unep.fr/scp/sun/publications

Linkages

- LIG-01 Lighting Levels (to optimise lighting levels)
- LIG-04 Lighting Upgrades (linkage to improved lighting efficiency)
- LIG-03 Daylighting (linkage to making maximum use of daylight)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

LIG-03
Daylighting

Benchmarks & Rules Of Thumb

- Where daylight is optimised in office environments, between 30 and 50% less artificial lighting is used
- Photo-sensor switches to reduce artificial lighting levels should be installed within 4-6 feet of the window zone

Introduction

The use of daylight in offices should be maximised in order to reduce the use of artificial lighting and the associated lighting power consumption. Strategies should be implemented that use reflected light in order to avoid direct sunlight and the associated affects of glare. In office areas not exposed to sunlight, strategies for maximising daylight infiltration should be used. In addition, lighting controls that switch off, or dim-down artificial lighting during day time should be used.

Approach

1. Compile an office layout defining windows, doors, atriums and other sources of incoming daylight.
2. Based upon these layout plans, a daylighting strategy should be developed focussed on reducing artificial lighting in areas with available daylight through a combination of the following measures:
    - The use of dimmer or dual level controls and photo-sensor switches. Re-wiring may be required.
    - Ensure blinds and curtains needed to shield from direct sunlight are open in the morning to avoid unnecessary use of artificial lighting (see ENV-06).
    - Paint walls in light colours to maximise reflectance, and consider the use of light shelves for allowing light penetration further into the office space (light shelves should be located above eye level and have a highly reflective upper surface.)
    - Installation of skylights or sun pipes (sealed for summer).
    - Consider office layout changes to optimise the use of daylight and avoid glare from direct sunlight, and changing partition materials to transparent or glazed materials.

Benefits

- A reduction of the artificial lighting load will lead to a reduction in energy consumption.
- It increases the quality of the working environment and improves the productivity of the employees.

Technical Requirements

- Technical know-how of lighting requirements, avoidance of glare effects and glazing reflectance.
- Expertise to implement the control methodology of the lighting systems
- Sustainable design expertise if office layout changes are to be considered.

Cost & Payback

- Individual controls can cost in the order of $500 to $1,000 to install with a typical 12-18 month payback.
- Other measures such as partitions, light shelves, sun pipes etc must be assessed on a case by case basis.

Risks

- The gain from daylight needs to be balanced against the potential heat gain and possible glare concerns (see ENV-03, 04 and 05).

Further Information

- www.veluxstiftung.ch/downloads/Innovation_Daylight_Scartezzini.pdf
- www.informedesign.umn.edu/_news/mar_v03-p.pdf
- www.daylighting.org/pubs/daylight_every.pdf
- erg.ucd.ie/mb_daylighting_in_buildings.pdf
- www.unep.fr/scp/sun/publications

Linkages

- LIG-01 Lighting Levels (to optimise lighting levels)
- LIG-04 Lighting Upgrades (linkage to improved lighting efficiency)
- LIG-02 Lighting Controls (linkage to associated control functions)
- ENV-03, 04 and 06 (links to glazing options to maximize daylight and reduce glare)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

LIG-04a
Lighting Upgrades — Lamps

Benchmarks & Rules Of Thumb

- The use of energy efficient lamps can reduce lighting energy consumption by up to 40%
- T8 lamps are approximately 10% more efficient compared to T10/T12 lamps
- T5 lamps are approximately 35% more efficient than T8
- LED lamps are up to 75% more energy efficient than incandescent lamps

Introduction

Over the last 10 years, a gradual change has been made to lower energy-consuming fluorescent and LED lighting tubes, which can reduce lighting power consumption by up to 40% while providing equivalent lighting levels. A change to low energy lighting fittings should be given priority both during re-lamping and refurbishment periods.

Approach

1. Compile an inventory of current methods of lighting lamps and fixtures.
2. Identify available replacement lamp options based on current ceiling grid pattern and associated costs. Develop a re-lamping strategy such as replacing T12 with T8 or replacing T8 with T5, or if maximum efficiency is desired, replace existing lamps with LED equivalents.
3. When specifying a fluorescent lighting system, always specify electronic ballasts and retrofit all magnetic ballasts with electronic ballasts (see LIG-04b).
4. When replacing existing fittings always ensure that automatic lighting level controls are installed based on occupancy and daylight levels (see LIG-02 and LIG-03).

Benefits

- Lighting improvements will reduce energy use and power demand, reduce heat production, lower life-cycle lamp cost and reduce maintenance needs.
- Replacement lamps can deliver better quality light (e.g. without the flickering) and can therefore also improve occupant satisfaction.

Technical Requirements

- Expertise to install the lamps and ballasts (or drivers in the case of LEDs).
- Technical know-how to maintain and schedule a maintenance plan for the lamps.
- Technical know-how to select replacement lamps. This should be completed in conjunction with a lighting design specialist and equipment supplier documentation.

Cost & Payback

- The price range is in the region between $150 and $300 per T5 or T8 luminaire and total cost depends upon the office size. The price differences can be balanced by reducing the number of lamps in a luminaire and by reducing the number of luminaires in a room (see LIG-01b)
- The payback will depend on the energy savings achieved as well as the tariff structure but is typically a 2-3 year period. A cost benefit analysis should be undertaken before re-lamping is undertaken.

Risks

- Spot re-lamping often results in the installation of a variety of lamp types with inconsistent light output levels, life spans and colour.

Further Information

- www.lrc.rpi.edu/programs/NLPIP/lightinganswers/pdf/view/LAT8.pdf
- www.unep.fr/scp/sun/publications
- www.energystar.gov/index.cfm?c=ssl.pr_commercial
- www.energystar.gov/index.cfm?c=lighting.pr_lighting
- www.energysmart.com.au/sedatoolbox/lightcalc.asp

Linkages

- LIG-01 Lighting Levels (to optimise lighting levels)
- LIG-04b, c and d Lighting Upgrades (linkage to improved lighting efficiency)
- LIG-02 Lighting Controls (linkage to reducing luminance levels
- LIG-03 Daylighting (linkage to making maximum use of daylight)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
X	5 - 10%
	>10%

LIG-04b
Lighting Upgrades — Ballasts

Benchmarks & Rules Of Thumb

- Typically 15-20% of total energy used in fluorescent lighting systems is lost in the ballasts as heat
- Changing from magnetic to electronic ballasts for fluorescent lamps offers around 20-40% energy savings associated with the lighting
- This measure is not relevant for LED lamps where ballasts are not used

Introduction

As part of a relamping exercise, full consideration should also be given to the types of ballast used with the new fluorescent lamps (note that LED lamps do not use ballasts). The lighting ballast controls the starting and operational voltages. High frequency electronic ballasts offer significant energy savings and other benefits compared to traditional low frequency magnetic ballasts. When combined with the fluorescent lamp changes (LIG-04a), greater energy efficiency and hence GHG emissions can be achieved.

Approach

1. Determine if the existing fluorescent lamps have low or high frequency ballasts. As a general rule, T12 lamps will typically be using magnetic ballasts and T8 and below will be using electronic ballasts. Note LED lamps do not require ballasts.
2. Consider the selection of the ballast based upon an appropriate lamp-ballast system and the relative ballast factor.
3. The aim should be that all occupied spaces with fluorescent lamps have high frequency electronic ballasts.
4. Consideration should be given to a phasing programme of replacement.

Benefits

- Changing from magnetic to electronic ballasts offers a 20-40% lighting energy saving.
- High frequency electronic ballasts operate at 20,000Hz or more, therefore the associated flicker rate cannot be detected by the eye, resulting in improved visual comfort relative to magnetic ballasts.
- High frequency electronic ballasts also prolong lamp life.

Technical Requirements

- Technical know-how for replacing ballasts.

Cost & Payback

- There is no major cost differences in purchasing high frequency electronic ballasts compared to magnetic ballasts, with individual ballasts costing between $50 to $300.
- The payback to cover the new purchase costs for replacement can be 2-3 years as part of a re-lamping exercise.

Risks

- Main risks relate to ensuring ballasts are properly installed, and are appropriate to the fluorescent lamps chosen.

Further Information

- www.lrc.rpi.edu/programs/NLPIP/pdf/VIEW/Guide2.pdf
- www.energyrating.gov.au/ballasts1.html
- www.lightsearch.com/resources/lightguides/ballasts.html

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- LIG-04a Fluorescent Lamps (linkage to improved lighting efficiency and the need to ensure the ballasts complement the fluorescent lamps)
- LIG-04c Emergency Lighting (linkage to improved lighting efficiency)

LIG-04c
Lighting Upgrades — Emergency Lighting

Benchmarks & Rules Of Thumb

- Replacement of emergency and exit lamps with LEDs can reduce associated energy consumption by 80-90% compared to incandescent bulbs
- LED lights also last up to 50 times longer
- Emergency and exit signs can be large electricity consumers due to their 24 hour operation

Introduction

Exit and emergency lighting and signs consume a significant amount of energy as they operate for 24 hours a day and 7 days a week. Incandescent lights were the first standard exit lights and are still commonly found in offices due to their lower cost. Incandescent lights are the least energy-efficient option and require the most maintenance as they have the shortest lamp life. Changing current incandescent or fluorescent exit lamps to Light Emitting Diodes (LEDs) will decrease the energy consumption.

Approach

1. Determine the location of all emergency and exit signs in the office.
2. Compile an inventory of the types and ratings of lamps used in the current exit signs.
3. Develop a replacement plan for substituting all lamps with LED equivalents.
4. Factors to consider when purchasing new LED exit signs include: colour of sign (green or red), battery backup, location and placement, applicable state and local building codes, appropriate casing material for application, and number of faces (single or double).

Benefits

- Reduction of the lighting load will lead to a likely reduction in energy consumption and hence a reduction in greenhouse gas emissions.
- LED lights have very low early failure rates and can last up to 30 years.
- LED lights require less power, so battery backup may last longer in case of an electricity outage.
- LED exit signs are usually brighter than incandescent or fluorescent signs, and have greater contrast with their background due to the monochromatic nature of the light that LEDs emit. This makes them more effective and safer for use in exit signs.
- Less cooling energy is needed due to less heat release by LEDs.

Technical Requirements

- Seek advice from lighting and safety experts before replacing the emergency exit signs.

Cost & Payback

- LED exit signs cost between $50-$100 or less if bought on a large scale and typical payback will depend on the building lighting load. For new installations there is minimal cost differential between LED and conventional fittings. A short payback often occurs typically within one year.
- Annual lighting energy costs associated with LEDs are 80-90% less than incandescent.

Risks

- Incorrect installation may lead to malfunctioning of the exit signs thus leading to inadequate lighting levels. This can have legal and safety implications if exit signs are at an adequate lighting.

Further Information

- www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs

Linkages

- This measure links to all of the other LIG measures as part of a holistic lighting strategy to reduce energy consumption and hence GHG reductions

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

LIG-04d
Lighting Upgrades — Down-lighting

Benchmarks & Rules Of Thumb

- Changing from incandescent lamps to compact fluorescent lamps offers an approximate 50% lighting energy saving
- If LED lamps are used, further energy savings are possible up to 80-90% compared to incandescent lamps

Introduction

A recessed light or down-light is a light fixture that is installed in a void opening in the roof or ceiling. Down-lights are commonly used for general illumination in lobbies, halls, corridors, stores and other finished spaces. Traditionally down-lights have been configured with incandescent lamps, also referred to as general lighting service (GLS) lamps, however replacement with compact fluorescent lamps (CFL) or LEDs offer energy efficiency savings and GHG emission reductions. Legislation in many countries is now starting to eliminate the manufacture and installation of traditional incandescent lamps and light sources.

Approach

1. Compile an inventory of recessed down-lights in the office and their function.
2. Look at the options available for using CFLs or LEDs to replace incandescent lamps based upon their function and use.
3. For applications requiring high-wattage incandescent or halogen lamps, consider metal halide down-lights, especially the new high colour quality ceramic metal halide lamps. There are also some LEDs that can meet these requirements.
4. When replacing incandescent down lights, take note of the following:
   - Go for a 3:1 wattage ratio. Lamp manufacturers publish a 4:1 ratio for replacing incandescent bulbs with CFLs (that is, a 25-W CFL can replace a 100-W incandescent lamp) but practice has shown that a 3:1 ratio is more appropriate (a 25-W CFL can replace a 75-W incandescent lamp).
   - Due to the wide range of sizes and shapes, limit the range of CFL types used in the office and this will be useful to standardise and also to reduce stocking requirements and eliminate any confusion during relamping.

Benefits

- CFLs and LEDs result in reduced energy consumption and also reduced cooling loads.
- Upgrading recessed down-lights can significantly reduce operating and maintenance.
- Reduced associated cooling costs due to reduced heat generation from CFLs.

Technical Requirements

- Require technical know–how to replace lamps and compile the inventory of down-lights.

Cost & Payback

- CFLs and LEDs cost slightly more initially than incandescent lamps do, but the payback is short due to the lower energy and maintenance costs.

Risks

- When upgrading down-lights, care must be taken in choosing the appropriate fixture in order to ensure that excess heat build-up does not shorten the lamp life.

Further Information

- diydata.com/electrics/downlights/down_lights.php
- www.energystar.gov/index.cfm?c=lighting.pr_lighting
- www.todae.com.au/LEDlighting/LED_Lighting_Guide

Linkages

- LIG-04ba Ballasts (linkage to need to ensure energy efficient ballasts are installed if CFLs are selected to replace incandescent lamps).

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

LIG-05
Exterior Lighting

Benchmarks & Rules Of Thumb

- Converting from mercury halogen to low or high pressure sodium lamps can save approximately 40% in lighting energy needs

Introduction

External lighting generally comprises security night lights where all lighting turns on at dusk and remains on all night until dawn, and general exterior lighting where the lighting is only operated when a given exterior area is occupied or in use. This exterior lighting can represent an important proportion of an office's total lighting energy consumption. A number of options exist to consider using low energy external lighting and controls to operate at varying levels depending upon the time of night-fall or occupant activities.

Approach

1. Prepare an inventory of existing exterior lighting fixtures, current and required operational hours, and the areas of use.
2. Undertake an exterior lighting survey and implement a re-lamping strategy for exterior lights. Control and manage the use of exterior lighting including the following:
   - Automatically activate exterior lights precisely at sunset using timers or sensors (ensure lights are not operational in hours of daylight).
   - Use stepped ballast and lamp systems for all exterior lighting applications, reducing light to the minimum necessary intensity to serve the function of the space it serves.
   - Combine occupancy-based and photosensitive control when occupancy is detected and it is dark.
   - Install panel-based astronomic clocks to turn exterior lighting on and off based on calculated seasonal sunrise/sunset changes.
   - Two types of energy-efficient high-intensity discharge lighting are widely available for exterior use: high-pressure sodium (HPS) lights and metal halide lights. LEDs are also emerging with some fixtures incorporating photo-voltaics and battery storage.

Benefits

- Reduction of lighting energy consumption and concurrent reduction in energy bills.

Technical Requirements

- Expertise to install the new lighting systems, controls and stepped ballasts.
- Technical know-how to conduct a lighting survey and undertake re-lamping strategy.

Cost & Payback

- The cost and payback will vary as it will depend on the tariff structure and schedule. It is recommended that a cost-benefit analysis be undertaken before a re-lamping or controls are installed.
- Controls on lighting systems cost around $500-$1,000 each to install and typically pay for themselves in 12-18 months.

Risks

- Security and health and safety requirements must not be compromised.
- Incorrect installation of control methods may lead to malfunction.

Further Information

- oee.nrcan.gc.ca/residential/personal/lighting/outdoor.cfm?attr=4#tips
- www.trianglemicrosystems.net/wp-content/uploads/2008/05/tms-lighting-brochure-single-sheet.pdf

Linkages

- This measure links to the other LIG measures as part of a holistic lighting strategy to reduce energy consumption and hence GHG reductions

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Annex A.4: Heating, Ventilation, Air Conditioning and Refrigeration (HVAC)

The 28 measures presented under this section fall under the main topics of controls, air distribution, air economiser, chillers and cooling, boilers and heating and motors.

The individual measures are summarised as follows:

Reference	Measure
HVAC-01: Controls	(a) Thermostats (b) BMS
HVAC-02: Air Distribution	(a) Air Balancing (b) Obstructions (c) Filter Cleaning & Upgrade (d) Eliminate Ductwork Leaks (e) Heat Exchanger Coils (f) Damper Blades and Linkages (g) Fans (h) Supply Air Temperature Reset (i) VAV
HVAC-03: Air Economiser/Free Cooling	
HVAC-04: Chillers & Cooling	(a) Water System Treatment (b) Chiller Maintenance (c) Water-side Economiser (d) Chilled Water Reset (e) Cooling Towers (f) Variable Primary Flow (g) Chiller retrofit
HVAC-05: Boilers & Heating	(a) Domestic Hot Water (b) Boiler Maintenance (c) Demand Needs (d) Hot Water reset (e) Insulation (f) Flue-Shut Off Damper (g) Oxygen Trimming (h) Economiser
HVAC-06: Motors	

HVAC-01a
Controls — Thermostats

Benchmarks & Rules Of Thumb

- Savings of up to 20% on heating/cooling loads can be achieved by ensuring that thermostats function correctly in the ranges required
- Programmable thermostats can be more responsive to room requirements and therefore further optimise energy savings

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

Ventilation of air serves the heating and cooling needs of spaces, as well as serving an indoor air quality (IAQ) function by preventing contaminant build up such as carbon dioxide. Ventilation rates can be adjusted to respond to the temperature and thermal comfort (see OPS-02), as well as IAQ requirements. Inappropriately located or poorly performing thermostats mean office spaces can be unnecessarily over-heated or cooled. This measure seeks to ensure that appropriate controls are in place and are suitably located to meet user space requirements. It also links to the use of thermostatic radiator values (TRV) where space heating is provided by hot water (HVAC-04c).

Approach

1. Compile the layout of the office that shows the air duct design, location of coolers and exhaust systems. Compile data of the operational requirements of the office such as number of occupants, design data on air change rates, temperature and humidity requirements (linkage to OPS-02).
2. From this information and based on the office zoning, the requirement for thermostats in each functional zone can be determined.
3. Select the appropriate type of thermostat required—examples include standard digital, programmable, remote controlled, heating and cooling anticipators and remote temperature sensors.
4. When locating and positioning thermostats, the optimum location is on a partition wall approximately 1.5m from the floor in a location with freely circulating air. Avoid placing them where they can be influenced such as near to radiators, in direct sunlight or near to air discharge grills.
5. Ensure the thermostats are appropriately linked to the systems they are intended to influence (so either direct to the AHU, or to the BMS).
6. For existing thermostats, check and calibrate that they are working, including that the set temperature (that set on the thermostat) and ambient temperature (actual room temperature) are within 2-3 degrees (see also OPS-02).

Benefits

- Thermostats can help optimise energy usage to suit the appropriate occupancy levels, by managing ventilation demand.
- Improves occupant comfort by enhancing the quality of air inside the building.

Technical Requirements

- A ventilation thermostat should be installed by a qualified technician. It should be possible for a building facility manager to personalise the load schedule with the use of the operating manual.
- Resources are required to provide training to building facility staff and managers to understand and facilitate operation and maintenance procedures.

Cost & Payback

- Programmable thermostats cost between $100 to $500 to install and typical payback is less than three years. The cost will depend on the level of control that will be provided by the controller.

Risks

- Incorrect installation may lead to malfunctioning.
- Ensure heating/cooling requirements do not compromise IAQ needs.

Further Information

- www.toolbase.org/Technology-Inventory/HVAC/programmable-thermostats
- www.hometech.com/learn/hvac.html

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-01b BMS (linking thermostats to BMS controls if in place)
- OPS-02 Thermal Comfort (linkage to thermal comfort settings and requirements of the office space areas and rooms)
- HVAC-04c Demand needs (links to the use of thermostatic radiator values)

HVAC-01b
Controls — Building Management Systems (BMS)

Benchmarks & Rules Of Thumb

- BMS can contribute significant energy savings of between 5-25%
- Poor BMS configuration and use (often manually over-ridden) can be responsible for energy losses of up to 20%
- BMS are generally not used in offices or buildings with an area of less than 10,000 m^2

Introduction

A BMS is a digital control system used to monitor and regulate the air quality and services within an office, through the control of both mechanical and/or electrical systems. Typical systems controlled may include lighting, heating and cooling systems, extraction, data networks, access control, emergency power, fire protection and security. Use of a BMS enables automated and responsive control of building systems, as well as performance improvement, and therefore offers energy efficiency opportunities. The effectiveness of BMS use does however depend upon the appropriate management and use of the BMS, and whether operatives are fully trained and understand the BMS functions. Manual over-ride of BMS is a frequent cause of poor building energy performance.

Approach

1. As a general guide, the use of a BMS should only be considered for larger office space, and offices where the UN has full system control.
2. Consult with a number of suppliers and/or an energy consultant to determine the type and scope of a BMS to be installed including which systems to be controlled.
3. In reviewing BMS options, it is important to consider the three main BMS functions of monitoring, controlling and reporting.
4. Ensure that the BMS brand to be installed meets the office's requirements.
5. Where the office has an existing BMS, it is recommended that a specialist contractor is engaged to ensure the BMS is fully functioning and calibrated, and operatives are fully trained.

Benefits

- A significant reduction in energy consumption is possible if correctly configured.
- Reduction in required labour and reliable control of services.
- Early fault detection through the detailed monitoring of all building services may assist in problems being rectified before significant damage takes place.
- Improved occupant comfort. Comfort is directly linked to productivity in the office environment.

Technical Requirements

- The correct installation of a BMS requires a technical understanding, and should only be undertaken by suitably qualified engineers with the necessary experience.
- Operation of the BMS should only be permitted by qualified operatives, with an appropriate understanding of the building services in use and the operation thereof.

Cost & Payback

- BMS are generally expensive to purchase and install, however energy savings of 5-25% are achievable with a return on investment of 2 - 3 years.

Risks

- The use of BMS are sub-optimal if incorrectly specified, installed by engineers that misunderstand the needs of the office, when settings are not updated to suit changes in building occupancy patterns, inadequate training is provided or the system is not correctly maintained.

Further Information

- www.modbs.co.uk/news/fullstory.php/aid/211/Building-management_systems_as_the_key_to_energy-efficient_buildings_and_reducing_greenhouse_gases.html
- www.energysmart.com.au/sedatoolbox/esm8.asp

Linkages

- HVAC-01a Thermostats (linking BMS to thermostat controls)
- OPS-02 Thermal Comfort (linkage to thermal comfort settings)
- Broader linkage to many of the other aspects of this Guide where a BMS can be used to provide automated control and management

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
	$10k - 100k
X	$100k - 500k
	>$500k

Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months

GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
	5 - 10%
X	>10%

HVAC-02a
Air Distribution — Air Balancing

Benchmarks & Rules Of Thumb

- Occupant complaints regarding thermal comfort settings, or uneven temperatures across the office could be a sign of imbalance in the air distribution
- Air balancing ensures HVAC systems are operating at their design conditions, and so can lead to energy savings through optimisation

Introduction

The procedure known as balancing is often the generic term used to describe the testing, adjusting and balancing of HVAC systems to achieve proper operation to achieve the desired air flow rates. The air balancing process can be in its simplest form checking that rooms feel comfortable, or at the other end of the spectrum it can be a fully certified and tested air balance. This measure therefore is focussed on checking and ensuring that all components of the HVAC are working in harmony and at their optimum performance.

Approach

1. It is recommended that the design requirements are established, and collated against actual performance data to verify that the design requirements are being met e.g. electricity, temperature, flow rates, HVAC commissioning records (such as design temperatures and flow rate) etc. From this exercise potential areas of concern could be identified.
2. Simple air balance diagnostics can be performed by holding out a hand in office spaces to feel air flow and temperature and gain feedback from office users.
3. For a fully tested air balance, a specialised HVAC contractor will be required to balance the airflow in an HVAC system, and to implement to changes identified as necessary. Modelling of the system on HVAC software may be required at times.

Benefits

- Balancing the HVAC system to run efficiently as per the design intent results in less strain being placed on the system equipment, decreasing operational costs. This in turn equates to energy and GHG savings.
- Increased occupant comfort.
- Equipment life expectancy may be prolonged as the components are operating as designed.
- Maintenance costs will be decreased.

Technical Requirements

- It is required that a qualified HVAC technician is commissioned to carry out air balancing beyond the simple inspections.

Cost & Payback

- The direct cost associated with air-balancing of an HVAC system will be the associated professional fees, however the subsequent recommendations may suggest the installation or replacement of faulty parts. Payback may be achieved rapidly (few months), depending on how poorly the system was initially operating.

Risks

- Some downtime will be required for testing, adjustment and balancing purposes; some facilities or applications may be highly sensitive to such activities.
- No significant disadvantages associated with the implementation of this measure.

Further Information

- www.airbalancingco.com/tutorial.html
- www.modular.org/Magazine/comfort02-03.aspx

Linkages

- Air balancing has linkages to all of the air distribution measures — air balancing looks at the overall system operation, but identified faults may be attributable to specific measures presented and described in the following parts of this Guide

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

HVAC-02b
Air Distribution — Obstructions

Benchmarks & Rules Of Thumb

- Obstructed extracts or diffuser outlets suggest poor housekeeping practices
- The obstruction of any building services should be avoided and the associated air flow pathways

Introduction

It is common to find air distribution patterns disrupted by placement of obstructions such as filing cabinets and desks against HVAC air duct outlets or extracts. This affects the system heating and cooling efficiency and can result in increased energy consumption in addition to poor air distribution.

Approach

1. The office as-built drawings should be studied in order to determine the location of all air outlets, diffusers and outlets.
2. Inspect each of these identified locations and ensure there are no direct blockages or obstructions and that sufficient space exists to allow for air movement and flow.
3. Temperature distribution monitoring might also assist in determining whether indoor air characteristics are as designed.
4. Remove obstructions to ensure that air flow and distribution is not impeded.

Benefits

- The removal of obstructions (and thus decreased pressure drop) ensures a uniform air distribution in terms of both temperature and volume, as intended by the design engineer.
- Indoor air quality is improved as building occupants are more comfortable, and thus more productive. This addresses the issue of "cold-air dumping".
- The risk to personal safety within the working environment is decreased through good housekeeping and the appropriate placement and storage of material.

Technical Requirements

- No technical requirements.

Cost & Payback

- The implementation of this measure is more likely to benefit user comfort than achieve significant financial savings.
- Good housekeeping and the elimination of obstructions can be implemented without cost, but may require some training to ensure that building occupants are aware of the associated risks and best practise. Savings in energy costs will be achieved immediately.

Risks

- No associated risks.

Further Information

- www.nzbcsd.org.nz/energyefficiency/content.asp?id=193

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-02a Air Balancing (linkage to diagnosing the potential for ductwork leakage and to give an indication of potential imbalances)

HVAC-02c
Air Balancing — Filter Cleaning and Upgrades

Benchmarks & Rules Of Thumb

- An excessive air pressure drop across the AHU air filter can require an increase of up to 50% in fan power to compensate
- Extended surface area filters have lower initial pressure drops and greater filter efficiency therefore offering energy efficiency savings

Introduction

The nature of screens and filters are such that they expose a very large surface area to passing air and particulate matter. As a result, even low levels of dust rapidly decrease the cross-sectional area, causing pressure drops which in turn require more fan energy to keep up flow rates. Therefore frequent cleaning and as necessary replacement reduces pressure drops and improves the associated energy efficiency of the ventilation system.

Approach

1. Identify and locate all main filters within the HVAC system.
2. Consult equipment O&M manuals and supplier recommendations to ensure that the recommended inspection (at least monthly) cleaning and replacement cycles are being followed (typically filters are changed on pressure drop or based upon a prescribed schedule).
3. Existing filters should be checked to ensure that they are the correct size and inspected for damage. The taking of differential pressure-drop readings can help in determining when a filter may need replacing.
4. During maintenance and cleaning, check that the air filter fits properly and tightly.
5. When replacing filters, look to upgrade with extended surface area filters which have a lower initial pressure drop and higher filter efficiency. It is recommended that all filters be replaced at the same time.
6. Be aware of activities external to the office that may require that filters be changed more regularly (for example construction projects nearby creating dust in the vicinity of the office).

Benefits

- The proper cleaning and maintenance of screens and filters will result in a reduced pressure drop and consequent increase in flow rates. This increase in flow rate will ensure optimum operation of the associated equipment, and exert less strain for an equivalent performance.
- Increased indoor air quality and user comfort.
- Blocked screens and filters are unhygienic and can promote the growth of various forms of bacteria that have been linked to health concerns.

Technical Requirements

- The cleaning of filters and screens would often be performed by maintenance staff, as stipulated in the building O&M manuals. This is unlikely to be technically challenging as most equipment is designed to incorporate maintenance requirements, but should preferably be performed by someone with a basic understanding of how the equipment operates.

Cost & Payback

- Other than the associated labour cost, the cost to implement will be negligible. Financial gains in performance and air quality will be experienced immediately.

Risks

- The risk of exposure to microbial activity and allergens is greater during the cleaning of filters.
- Persons tasked with cleaning the filters should ensure that dirt from the screens is not dislodged within the intake ducts or manifolds.
- Ensure during cleaning that condensate drip pans are also emptied and properly cleaned.

Further Information

- www.epa.gov/iaq/schooldesign/hvac.html

Linkages

- The inspection and checking of filters should be an essential first step before all of the other HVAC air distribution measures are considered

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-02d
Air Distribution — Eliminate Ductwork Leaks

Benchmarks & Rules Of Thumb

- Leaks in ductwork can account for up to 20% of heating and cooling costs for an office
- Duct leakage can prevent a large amount of supply air, typically 20-40%, from reaching its intended destination in the office

Introduction

Duct systems are used to distribute conditioned air through offices with forced-air heating and cooling systems. Air loss in ductwork due to leaks, punctures or poor duct connections, can lead to pressure loss, as well as heat/cooling losses. This leads to increased heating/cooling and fan power requirements, therefore more energy. Systematic checking can help ensure leaks are minimised and therefore energy is saved.

Approach

1. A routine ductwork inspection plan should be developed and implemented.
2. As a first step, look for evidence of potential duct air losses such as higher than usual energy bills, difficulty in heating/cooling areas or stuffy/uncomfortable rooms.
3. Review as-built HVAC drawings to identify ducting routes and dimensions, accessibility and potential problem areas. Areas with flex ducting should be a priority due to possible disconnection or damage. Also look at insulation integrity.
4. The use of a professional contractor is recommended for identifying and eliminating HVAC ductwork leaks. The use of several different instruments could be used for leak detection, the operation of which will require a suitable level of proficiency.
5. Ad hoc leak elimination can be performed by a technician or person with a reasonable understanding of the system operation, however this activity will only address obvious problems.
6. Repair or replace damaged ducts or leaks. Air flow tests can be performed after sealing repairs.

Benefits

- Reducing the level of air losses allows fan speeds to be reduced with a subsequent reduction in motive power and heating / cooling input requirements.
- Ensures operational alignment to design conditions. User comfort will be improved as the rooms become adequately heated or cooled.
- A potential reduction in energy losses and financial saving is achieved.

Technical Requirements

- The use of a professional contractor is recommended for identifying and eliminating HVAC ductwork leaks.

Cost & Payback

- Leak elimination does not require extensive capital outlay and payback can be achieved within a short period of time.

Risks

- No operational risks. This activity simply aims to rectify poor performance to suit the operational conditions as commissioned.

Further Information

- www.austinenergy.com/energy%20Efficiency/Programs/Green%20Building/Sourcebook/ductWork.htm

Linkages

- ESD-02 Metering and OPS-01 Energy Bills (spotting usual energy consumption may indicate potential air losses through leaks)
- HVAC-02a Air Balancing (linkage to diagnosing potential for ductwork leakage)

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

HVAC-02e
Air Balancing — Heat Exchanger Coils

Benchmarks & Rules Of Thumb
- Fouling may start after 200 - 400 hours operation in condensers or less if external fouling by dirt or fallen leaves
- Energy savings of the order of 10-20% of the heating/cooling energy load can be achieved by cleaning heat exchangers and condensers

Introduction
Efficient heat transfer requires clean surfaces for air or fluids through coils or finned heat exchange surfaces. This measure focuses on the cleaning of air-side surfaces (water treatment is dealt with in measure HVAC-04). The fouling of coils (e.g. due to build up of dust and debris or dirt and fallen leaves on external condensers) reduces the efficiency of the heat transfer process and will result in a higher energy consumption. Cleaning can eliminate these problems—the greater the exposed surface area, the greater the rate of transfer.

Approach
1. Identify all air-side heat exchange coil locations and maintenance and cleaning requirements from the O&M manuals, as well as any associated pressure-drop monitoring needs.
2. Review the facility maintenance schedule to establish existing practices.
3. Prepare visual inspection reports and then survey to establish the extent of fouling and scope for improvement.
4. Implement required cleaning activities for fouled heat exchange coils, and examine route-cause of the fouling.
5. The best strategy is to prevent coils from becoming dirty in the first place through regular maintenance and cleaning.

Benefits
- A clean coil has a lower water-side and air-side pressure drop and thus lowers fan and pump energy consumption.
- Design temperatures are achieved without excessive fan or pump loads. This may also assist in reducing noise or vibration.
- Decreased additional maintenance costs.

Technical Requirements
- Implementing this measure requires a basic understanding of how heat exchangers operate. The person tasked with this role is to be able to identify the mentioned apparatus, and remove dirt and unwanted material without damaging the equipment or endangering themselves or other employees.
- Suitably trained maintenance staff should be able to perform this function.

Cost & Payback
- The cost of cleaning depends on the heat exchanger construction and the method of cleaning employed; plate, shell and tube, and air-cooled heat exchangers all require different forms of cleaning.
- The payback on heavily fouled equipment can be achieved rapidly, savings of 10 -25% are possible.

Risks
- Care should be taken not to bend or fracture exposed finned tubes.

Further Information
- www.p2pays.org/ref/26/25985.pdf

Linkages
- HVAC-04e Water Towers and HVAC-04a Water Systems (linkage to liquid side of the heat exchange systems)
- HVAC-02c Filter Cleaning and Upgrade (could be linked to filter efficiency if air side heat exchange components are getting easily fouled)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-02f
Air Distribution — Damper Blades and Linkages

Benchmarks & Rules Of Thumb

- If the inspection and maintenance of louvers and dampers is undertaken as part of standard maintenance procedures, this measure will not cost money and any identified savings will be immediate

Introduction

All adjustable louvers and dampers should be routinely inspected for damage or problems. A common fault is to find that the dampers / louvers are still being 'driven' by the control systems but the linkages or damper blades are damaged, which leads to either a higher heat or cooling load and subsequent increase in energy consumption.

Approach

1. All louvers and dampers should be checked for freedom of movement. Shafts, bearings, pivot points, etc. should be cleaned and lubricated with a light spray oil.
2. Blades should be checked in the closed position to ensure tight closure. Adjustments should be made at linkage to correct any misalignment.
3. Blades should be checked for freedom of movement. Blades should be disconnected from their operators and manually checked. (Blades should move freely with no binding or twisting.)
4. Pins, straps and bushings should be checked for wear, corrosion or rust. Replace or paint as required.
5. Check louver or damper blade edge and seals (where applicable).
6. Check all linkage, connecting bars and operator connections for proper alignment and fit.
7. Check overall installation to ensure that the louver or damper was installed in a plumb and square position and proper clearance has been allowed for blade, linkage and operator movement.

Benefits

- Properly maintained linkages and damper blades ensure that the correct volume of air is supplied to the selected location and therefore lowers the associated energy consumption.
- Indoor air quality and occupant comfort is improved.
- Higher confidence in safety-related systems.
- Reduced equipment degradation and replacement.

Technical Requirements

- Testing should be carried out at a frequency that fully assures the required equipment reliability.
- Maintenance activities may be undertaken by the on-site maintenance staff or experienced HVAC technicians.

Cost & Payback

- It is imperative that critical areas have properly functioning HVAC systems and the costs are normally contained within normal maintenance practices.
- If no large replacements are required and only labour costs are incurred, payback on this measure will be rapid.

Risks

- The maintenance of HVAC dampers and linkages does not promote risk; regular maintenance should minimise any risk associated with the operation of the mentioned equipment.
- Maintenance activities may require some equipment downtime.

Further Information

- www.betterbricks.com/DefaultPage.aspx?id=593
- www.safeair-dowco.com/damper_maintenance.asp
- www.safeair-dowco.com/louver_maintenance.asp

Linkages

- HVAC-02 Air Distribution (links to most aspects of air distribution)
- HVAC-03 Air Economiser / Free Cooling and HVAC-02h Supply Air Temperature Reset (damper plays an important role in the economiser role)

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-02g
Air Distribution — Fans

Benchmarks & Rules Of Thumb

- The fans that move the heated and cooled air through an office typically consume approximately 10% of the total energy consumed
- Reducing a fan's speed by 20% can reduce its energy requirements by nearly 50%

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

This measure covers two elements—firstly fan maintenance and secondly fan speed modulation for variable air flow systems. Fans typically provide years of trouble free operation for minimum maintenance, however this reliability can lead to complacency and therefore maintenance can be neglected. Appropriate maintenance can ensure efficient fan operation. Variable air volume (VAV) systems (see HVAC-02i) allow responsive volume and flow control, therefore the fans supplying the air also need to respond to this variation. Control dampers waste energy and hence have become obsolete and been replaced by fan modulation. Significant power savings in fan motive power and heating / cooling can be achieved by reducing the fan speed levels to minimum acceptable levels.

Approach

1. With respect to maintenance, follow established preventative-maintenance protocols for cleaning housings and fan blades, lubricating and checking seals, adjusting belts, checking bearings and structural members and tracking vibrations.
2. Vibration analysis is a good predictive maintenance practice on large fans. Vibration signatures are compared to previous readings for indications of component degradation such as worn bearings, shaft alignment or fan blade imbalance.
3. For VAV systems, determine whether the existing fans have control, and if not investigate the possibility of implementing fan speed control through variable frequency drives (VFD).

Benefits

- Ventilation fan controls are easy to implement and can be installed in new or existing buildings.
- Fan speed can be programmed to fit specific occupancy patterns and indoor air volume so energy losses may be minimised while comfort is maximised.
- Reduction in energy losses will decrease energy consumption, energy bills and greenhouse gas emissions.

Technical Requirements

- Expertise is required for the installation of the VFDs.
- Technical know is required to analyse the cost and benefits before ventilation fans are fitted with VFDs.
- Specialist contractors would be required for vibration analysis.

Cost & Payback

- Maintenance costs should be part of routine maintenance programme.
- The fan controls can cost anything between $100 and $200 to install but it will depend on the control features available.
- The operation cost of fan controls will depend on the fan characteristic, operational schedule and the climate.

Risks

- Incorrect installation of any fan controls may lead to malfunctioning of the fans which in turn can lead to undesirable ventilation conditions.

Further Information

- www.toolbase.org/Technology-Inventory/HVAC/ventilation-control-systems

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-02 Air Distribution (fans have linkages to all of the air distribution measures)
- HVAC-02i VAV (fan speed modulation is typical when VAV systems are in operation in the office)

HVAC-02h
Air Distribution — Supply Air Temperature Reset

Benchmarks & Rules Of Thumb

- Simultaneous cooling and heating is a common source of energy wastage in air systems
- Energy savings of 5-10 % are not uncommon through implementation of this measure
- This measure is mainly applicable to HVAC systems with suitable control mechanisms such as a BMS

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not always applicable to humid and hot climates.	

Introduction

This measure relates to the potential energy wastage caused when the supply air temperature is too low, especially when the office is in heating mode. Air systems with heating and cooling normally use economiser control to modulate outdoor air and return air dampers to bring in cooler outdoor air thus avoiding mechanical cooling. The supply air temperature is usually set as a constant, and is usually selected to satisfy the maximum cooling load conditions. This means heating can be needed to reach desirable, as opposed to minimum levels. By looking at feedback from sensors in various zones (typically through a BMS—see HVAC-01b), the supply air temperature can be reset to a higher value. This will minimise the amount of simultaneous heating and cooling. This measure can be used in both constant and variable volume air systems.

Approach

1. Establish the occupancy and operational schedule to determine where and when specific areas within the air-conditioned area are occupied. Establish the associated design and measured data (if available) of supply and ambient temperature of the office for the different zones.
2. Establish what controls are already in place for the HVAC system and the viability of adding in the required supply air temperature reset controls, which require direct digital control (DDC) sensors in the discharge air and space sensors to provide space temperature feedback. The control algorithm will look for the warmest (or coolest) zone and adjust the supply-air temperature accordingly.

Benefits

- An air-side economiser is more beneficial when the supply air temperature is rest. When outdoor air is cooler than the supply air temperature set point, compressors are shut off and outdoor and return air dampers modulate to deliver the required supply air temperature. A warmer supply air temperature set point allows the compressors to be shut off sooner and increases the number of hours that the economiser is able to provide the necessary cooling.
- In summary this measure will optimise energy usage to suit the appropriate occupancy levels of the building, thus leading to a current reduction in energy bills and GHG emissions.

Technical Requirements

- Technical expertise is required before a supply air temperature reset system is installed to consider issues like HVAC modelling, zoning and integration.

Cost & Payback

- Depends upon the investment needed to upgrade, but for instances where controls already exist, the cost and payback can be quick.

Risks

- Incorrect installation may lead to malfunctioning which in turn can lead to undesirable temperatures for working conditions.
- In non-arid climates, warmer supply air means less dehumidification and therefore higher humidity, therefore this can be a constraint to this measure. Similarly in hot climates, there are relatively few hours in the day when the outside air can be used.

Further Information

- highperformancehvac.com/ddc_vav_systems.html
- hpac.com/mag/energy-saving-rooftop-vav-0429/

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
X	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-02 Air Distribution (links to most aspects of air distribution)
- OPS-03 Air Economiser (directly related to the economiser cycle and the outdoor air)

HVAC-02i
Air Distribution — Variable Air Volume

Benchmarks & Rules Of Thumb

- VAV best applies to offices with mixed layouts and varied uses
- VAV can save up to 25% on air distribution and heating/cooling costs
- VAV upgrades can incur significant upfront capital costs, but paybacks can be within 5 years

Introduction

The concept of Variable Air Volume (VAV) relies on the throttling of air volume to control temperature, and thus save energy during partial load conditions. Constant volume systems can be changed to VAV, and it best applies for offices with mixed layouts and rooms reflecting varied uses. Such an approach is energy efficient, optimises air flow and thus saves energy through a reduced load on the building air handling units.

Approach

1. Historical data relating to the operational requirements of the building occupants is required for zoning purposes, and to understand where the most demand exists.
2. The changing of constant volume systems to VAV is a significant undertaking and therefore a thorough feasibility study of cost and design impacts must be considered.
3. The VAV system must be designed so that it will deliver the required amount of outdoor air to each space it serves not only under the conditions that prevail on the cooling design day, but under the full range of weather and load conditions that can be expected, and under the range of space ventilation rates and system airflows that the system will deliver to meet those loads.
4. The design should consider reducing the static pressure set point to the minimum required to deliver air to remote outlets.

Benefits

- Air quality and comfort are greatly enhanced, with improved zoning capability.
- VAV systems are very flexible and can be adapted to suit changing design conditions or office uses.

Technical Requirements

- The services of suitably experienced mechanical engineers and HVAC technicians would be required for the design and installation of a VAV system.

Cost & Payback

- VAV can incur high initial costs for offices that require multiple zones.
- The energy savings experienced are highly variable and system dependant, with reported payback ranging from 1 to 5 years.

Risks

- Low flow rates from supply diffusers may result in poor mixing with existing air.
- Dumping of cool air from overhead diffusers can cause occupant complaints.
- Most disadvantages experienced with VAV systems are as a result of errors or omissions in the design, construction and operation, and can often be corrected.
- Large ductwork may result in space constraints in ceiling voids.
- In order to maintain sufficient comfort levels, VAV relies upon a significant amount of reheating .

Further Information

- highperformancehvac.com/ddc_vav_systems.html
- www.annex36.com/eca/uk/03viewer/retrofit_measures/pdf/retrofit_measure_solar_ac.pdf

Linkages

- HVAC-02g Fans (fan speed modulation is typical when VAV systems are in operation in the office)
- HVAC-02h Supply Air Temperature Reset (works well in VAV systems)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
X	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

HVAC-03
Air Economiser / Free Cooling

Benchmarks & Rules Of Thumb

- Free cooling is highly dependant on ambient conditions, and cannot be implemented effectively in hot humid climates and during certain periods in the year
- Annual savings of up to 5-10% of heating and cooling costs are possible in appropriate climates

Introduction

This measure seeks to take advantage of the differences between the outside ambient air temperatures relative to the required internal office temperatures. During summer months, cooler outside air in the mornings can be brought into the office to reduce the subsequent start-up cooling requirements, and during winter months the external dampers should be closed and warm air from internal heat gains circulated prior to the heating start up to provide an element of space heating. The systems should also be set to allow a significant gap between the operation of chillers in the summer and boilers/heating in the winter to prevent simultaneous heating and cooling.

Approach

1. Develop a building occupant schedule and associated weather and external temperature profile to determine when pre-cooling / pre-heating opportunities exist.
2. Ensure the office has an economy cycle — a large fresh air intake, spill/relief air outlet and a damper.
3. In the summer months, use cooler morning air prior to office start up times to reduce subsequent artificial cooling requirements. In addition, the building could be pre-cooled during off-peak hours using thermal storage e.g. ice storage to reduce the peak load on the chiller water plant.
4. In winter months ensure the external damper is closed during morning warm-up to ensure warm air from internal heat gains is circulated prior to the commencement of space heating. Minimum fresh air will need to be brought in during occupied hours.
5. This approach can also be applied during the daytime when the ambient air is at an appropriate temperature to mean that cooling or heating systems need not operate.

Benefits

- The practice of free cooling reduces energy demands at peak times.
- Indoor air quality can be improved when air side free cooling options are employed by flushing out the occupied space with outdoor air thus improving occupant comfort.
- Peak heating and cooling loads are reduced.

Technical Requirements

- This measure may be implemented manually, or be set to operate automatically. Automatic operation is preferred as it places fewer burdens upon the occupants, and is guaranteed to take place. Building Management Systems can also utilise an adaptive control algorithm that optimises the start time of equipment thereby maximising possible energy reduction and savings.

Cost & Payback

- Annual savings of up to 5-10% of heating and cooling costs are possible, depending on the building, climate and local energy costs. Costs to implement will vary depending upon what system changes might be needed to allow this to happen.

Risks

- If this measure is performed manually, care should be taken not to overheat or overcool a particular space, as this could have adverse effects on occupant comfort levels.
- Free cooling is highly dependant on ambient conditions, and cannot be implemented effectively in hot humid climates and during certain periods in the year.

Further Information

- mail.mtprog.com/CD_Layout/Day_3_23.06.06/1115-1300/ID59_Breton_final.pdf
- www.sv.sustainability.vic.gov.au/manufacturing/sustainable_manufacturing/resource.asp?action=show_resource&resourcetype=2&resourceid=32

Linkages

- ESD-03a Energy Tariffs (understanding tariff structure can focus on reducing peak loads)
- OPS 03a Minimise Load Peaking (pre-cooling and pre-heating can reduce load peaking)
- HVAC-02h Supply Air Temperature Reset (further use of the economiser cycle)
- HVAC-01b BMS (can help automate this approach)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not always suitable for hot and humid climates	

Capital Cost (US$)	
X	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
X	5 - 10%
	>10%

HVAC-04a
Chillers and Cooling — Water System Maintenance and Treatment

Benchmarks & Rules Of Thumb

- Appropriate maintenance and water treatment can lead to system performance improvement and efficiencies of the order of 10-20%

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

HVAC water distribution systems can often have hidden performance issues, such as the build up of scale and sludge, strainer blockage, leakage and corrosion, that can lead to excessive energy consumption through excessive wear on equipment. Appropriate maintenance and water treatment schedules can minimise the poor performance and hence energy inefficiencies.

Approach

1. The office's HVAC water distributions systems should be understood and mapped through as-built drawings and O&M Manuals. Examples of such water systems include chilled, heating and condenser water.
2. Routine maintenance must be undertaken following O&M Manual guidance, which as a minimum should include:
   - Adequate water treatment following supplier recommendations, and water filtering;
   - Inspection of insulation to eliminate energy losses;
   - Cleaning of condensers;
   - Valve inspections for noises which may suggest over-pressurisation and system imbalance;
   - Pump efficiency testing and associated differential pressure set-points; and
   - Leak inspections (which can be through meter readings).
3. Where system errors or malfunction are identified, implement appropriate remedial measures.

Benefits

- Optimises system performance and therefore ensures energy savings and GHG reductions.
- Appropriate water treatment can avoid the need for expensive system repairs and can ensure the control of pathogens such as *Legionella*.

Technical Requirements

- The inspections can typically be undertaken in house, however required repairs and water treatment may need to be performed by qualified technicians and engineers.

Cost & Payback

- Assuming these steps are part of the standard office inspection and maintenance schedule, costs will be negligible and benefits will be seen immediately.
- Costs may be incurred where repairs or upgrades are needed.

Risks

- Maintenance requirements and water treatment must be undertaken in conjunction with associated improvement measures such as chiller and cooling tower maintenance to maximise benefits.

Further Information

- www.betterbricks.com/DetailPage.aspx?ID=546
- www1.eere.energy.gov/industry/bestpractices/tip_sheets_pumps.html

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-04b Chiller Maintenance and HVAC-04e Cooling Towers (linkage exists as both of these have water delivery systems)
- HVAC-02e Heat Exchangers and Coils (for air-side treatment to ensure heat exchanger efficiencies)

HVAC-04b
Chillers and Cooling — Chiller Maintenance

Benchmarks & Rules Of Thumb

- Chillers should be brought to and maintained at peak operating efficiency
- Poorly-maintained chillers may use up to 25% more energy to provide the same quantity of cooling from a well-maintained chiller

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

Over time the efficiency of refrigeration equipment can change due to a combination of ageing equipment and often changing requirements for cooling within an office. Ensuring maintenance is completed, inspecting actual operation of plant for faulty linkages and dampers and cooling towers or recirculation optimisation will help to reduce the power used in these systems. The key is to bring the chiller to peak operating efficiency and then ensure this peak efficiency is maintained.

Approach

1. Review existing O&M plan, manuals and logbooks of the chillers.
2. Undertake required annual, monthly and weekly checks and maintenance tasks such as keeping logs of operating performance, checking starter and controls, operating pressures, refrigeration charges (see REF-01) and compressor inspections.
3. Follow manufacturer's guidelines for testing such as oil (for destructive acids), oil filter (for metal deposits) and the refrigerant (for moisture, acid or rust).
4. The correct refrigerant charges should also be assessed (see REF-01)
5. Where problems are identified, implement the recommended remedial measures as per the manufacturer's guidelines and the O&M manual.

Benefits

- Optimised and more efficient operation of the chiller plant
- Reduction in energy usage that will lead to a concurrent decrease in energy bills and GHG emissions.

Technical Requirements

- A maintenance program will need to be developed by an HVAC specialist in conjunction with the water treatment specialist, reliability department and the on-site maintenance staff. The equipment O&M manuals should be consulted during this process.
- An operating log is vital to good chiller plant maintenance and will assist in identifying trends in chiller performance. While the existence of a log is common practice, it is important to enforce accurate and consistent recording and review of the recorded data.

Cost & Payback

- Chiller system maintenance is not expensive if considered in terms of equipment degradation, potential system failure and the associated consequences. The cost and payback period are highly dependant on the extent of the program and the nature of the facility.

Risks

- Maintenance by unqualified and inexperienced technicians can actually worsen chiller performance.

Further Information

- www.facilitiesnet.com/hvac/article/5-Threats-to-Chiller-Efficiency--1893
- www1.eere.energy.gov/femp/operations_maintenance/om_ctchecklist.html
- www.betterbricks.com/DetailPage.aspx?ID=539

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k

Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months

GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-04a Water Distribution Systems and HVAC-04e Cooling Towers (linkage exists as both of these have water delivery systems)
- HVAC-02e Heat Exchangers and Coils (air-side treatment of heat exchanges)
- REF-01 GHG Compound Management (management of refrigerant levels)

HVAC-04c
Chillers and Cooling — Water-Side Economisers

Benchmarks & Rules Of Thumb

- Water-side economisers make use of outside ambient air temperatures to cool water
- Water-side economisers are have been used frequently to efficiently meet the cooling requirements of data centres

Introduction

Water-side economiser represents an energy efficiency approach in offices where chilled water is used for cooling requirements. It applies the same principles as air free cooling (see HVAC-03) but for the water circulation, where cooling energy is saved by using the cooling towers directly when the outside air temperature is suitable, rather than operating the chillers.

Approach

1. Determine the cooling energy load and with the daily, weekly and seasonal demand patterns and the operational hours of the office building.
2. Undertake an audit to determine the current cooling infrastructure in place and the process used in the office.
3. If it is identified that chilled water currently meets the cooling requirements for the office building, or the building has significant cooling limitations from air side economisers, undertake a feasibility study to identify potential benefits and savings that can be achieved from the installation of water-side economisers. A key issue with a water-based free-cooling system is calculating the peak cooling load and sizing.
4. If water-side economisers are implemented to meet cooling requirements, ensure that the current O&M plans for the HVAC system reviewed to incorporate the O&M of the economisers.

Benefits

- Water-side economisers do not require large outside air and relief air ducts and associated louvers.
- The implementation of water-side economisers can lead to the optimal use and efficient operation of cooling towers and chiller plants.
- Balancing cooling energy requirements and demand by installing water-side economisers can concurrently lead to a reduction in energy bills and greenhouse gas emissions.

Technical Requirements

- Technical expertise is required to undertake cost benefit analysis and feasibility study before water-sided coolers are implemented. A qualified chiller specialist or HVAC engineer should undertake the installation and commissioning of the water-side economiser.
- Similar to air-side economisers, this technology depends on design and controls in order to function optimally, hence it is imperative to have qualified operational and maintenance personnel for optimal functioning. When using a water-side economiser, the condenser water system should have a separate discharge temperature set point in the free cooling mode.

Cost & Payback

- Capital cost for economisers are high and payback will on various factors and hence a cost benefit analysis should be undertaken before an investment decision is made.

Risks

- Water-side economisers can be very effective, but in most cases should be operated via a water-to-water heat exchanger to avoid mixing water that flows through the compressor cooling tower.
- The components of the water-side economiser must be operated and maintained properly in order to realize estimated savings.

Further Information

- www.computerwoche.de/fileserver/idgwpcw/files/1437.pdf
- findarticles.com/p/articles/mi_m0BPR/is_9_19/ai_91964478/?tag=content;col1
- hightech.lbl.gov/documents/DATA_CENTERS/hpac_dc_bestprac.pdf

Linkages

- HVAC-04a Water Distribution Systems and HVAC-04e Cooling Towers (linkage exists as both of these have water delivery systems)
- HVAC-03 Air Economiser (same principles applied)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not always suitable for hot and humid climates	

Capital Cost (US$)	
	No cost
	$0 - 10k
	$10k - 100k
X	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

HVAC-04d
Chillers and Cooling — Chilled Water Reset

Benchmarks & Rules Of Thumb

- An increase of 3 – 5℃ in the chiller supply water may be possible, where energy savings of up to 4% per ℃ increase in chiller set point temperature are possible
- Direct digital control of the chilled water reset can achieve approximately 50% more energy savings compared to manually adjusting the system

Introduction

For the majority of time (up to 99%), offices are not operating at the peak design conditions, such as during milder outdoor temperatures or lower humidity. The cooling load is therefore less than design requirements. For chilled water systems, chilled water temperatures are often maintained at constant levels throughout the year defined by the maximum design cooling loads. During periods of low cooling load, it is possible to raise the cooling water flow temperature while still satisfying the actual cooling needs and therefore reducing the power input required into the chillers.

Approach

1. Establish the occupancy and operational schedule and the associated loadings, as well as the external year round conditions such as temperature and humidity in order to identify opportune periods for implementation of this measure.
2. The simplest and cheapest method is to reset the chilled water temperature manually at the chiller control panel. A table of chilled water settings will need to be developed and followed as this approach will require constant change and amendments of the temperature to suit occupancy and external conditions.
3. The alternative to manually making the changes is to utilise a direct digital control (DDC) to automatically control the rest temperature.

Benefits

- A decrease in energy and running costs is achieved.
- If the replacement of equipment is being considered, units of lesser capacity could possibly be purchased, which will produce a savings in capital expenditure.
- Since chillers are responsible for a large percentage of an office's electrical consumption, an increase in chiller temperature will also assist in reducing the maximum electrical demand.

Technical Requirements

- A specialist HVAC engineer may be needed to advise on both manual or DDC approaches.

Cost & Payback

- The cost for manual control is negligible and may include a minor labour fee.
- The installation and cost of a specialised reset controller (automatic) could cost several thousand dollars.
- Either method of control will decrease energy consumption immediately. Payback for larger systems can be achieved within one year, while smaller systems may be longer.

Risks

- Pumps and fans will be required to increase the flow to achieve the same level for the same level of cooling, therefore the potential energy usage by the fans and motors should be assessed against the chiller savings.
- Manual control requires effort on the building managers part and may be neglected. Finding the optimum chilled water temperature is an iterative procedure, and will not be achieved at a first attempt.
- Care needs to be taken that the chiller unit is able to meet the required cooling loads following any adjustment.

Further Information

- www.energybooks.com/pdf/264266.pdf
- www.betterbricks.com/DetailPage.aspx?ID=539

Linkages

- HVAC-04c Water-Side Economiser (to ensure the two approaches are coordinated)
- HVAC-04e Cooling Towers (linkage exists to the condenser waters)
- HVAC-02h Supply Air Temperature Reset (for air-side treatment to maximise opportunities)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

HVAC-04e
Chillers and Cooling — Cooling Towers

Benchmarks & Rules Of Thumb

- The temperature of water leaving the cooling tower should be as cold as the manufacturer will allow for returning condensate water
- Ideally the water should be 2℃ higher than the amb ient temperature

Introduction

Cooling towers are used to reduce the water temperature to the required condenser temperature set point. A number of options exist to save energy during the maintenance and operation of cooling towers relating to issues such as fans, water temperatures and sequencing. These energy efficiency opportunities link back to other measures described for chillers (see HVAC-04 series).

Approach

1. Assess the cooling tower maintenance and inspection needs based upon the O&M Manuals.
2. Ensure an appropriate maintenance strategy is implemented that considers issues such as:
   - Water treatment (for both biological growth control and avoidance of scaling); and
   - Nozzle cleaning and moving parts.
3. Consider and investigate the opportunities for a condenser water reset strategy—the aim would be to balance the water temperature at optimal levels, ideally the temperature set point of the water leaving the cooling tower being as low as possible.
4. Where possible, cooling towers should be operated simultaneously to rely on natural draft (i.e. no use of fans) to reduce energy consumption.
5. Fans should be checked for efficiency performance (see HVAC-02g for suitable guidance) and also be upgraded where required to optimise performance.

Benefits

- Optimised and more efficient operation of the cooling tower, as well as the chiller plant.
- Maintain temperature and lower energy consumption.
- Reduction in energy usage that will lead to a concurrent decrease in energy bills and GHG emissions.

Technical Requirements

- Cooling tower experts should be contracted to assess and implement cooling tower fan control schemes and advise on temperature reset strategies.

Cost & Payback

- The cost and payback will depend upon the measures implement and the associated scale of these. Water temperature reset strategies may by minimal cost items but offer immediate payback, whereas fan upgrades may present longer payback periods.

Risks

- Correct set-up of improvement measures is needed to ensure the cooling tower system is operating at optimum performance.

Further Information

- wea-inc.com/pdf/tower-fan1.pdf
- www.amtechresearchlabs.com/Doc/TB%20Cooling%20Tower.pdf
- www.betterbricks.com/DetailPage.aspx?ID=538

Linkages

- HVAC-04c Water-Side Economiser (to ensure the two approaches are coordinated)
- HVAC-04d Chilled Water Reset (linkage exists between the two reset strategies)
- HVAC-02g Fans (for further information on fan management)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-04f
Chillers and Cooling — Variable Primary Flow

Benchmarks & Rules Of Thumb

- The implementation of a variable primary flow system provides an average improvement of around 15% in chiller efficiency which equates to an approximate 25% energy saving
- This approach only works for offices with multiple water-cooled chiller units

Introduction

This measure is applicable to water-cooled chillers. The objective is to take advantage of off-design conditions (which occur for over 90% of the time) to allow operating conditions to respond to varying flow and changes in temperature whilst still ensuring energy efficient performance. One chiller in a maximum operating range is more energy efficient than two chillers at partial load. Therefore this measure seeks to convert the system to variable primary flow to take advantage of this position.

Approach

1. Conversion of existing systems to primary variable flow requires specialist technical expertise to review viability of existing systems to be upgraded. Consideration would need to be given to a number of factors including:
   - Replacement of AHU valves to ensure tight closure;
   - Removal of balancing valves that do not serve as isolation or service valves;
   - Interlock primary pumps to run with chillers they serve;
   - Variable frequency drives on pumps;
   - Installation of a check valve in the decoupler connecting the chilled-water supply and return mains to prevent return water from mixing with supply water;
   - Revision of the chiller control panel including temperature reset points; and
   - Linkages to cooling tower fan operations.

Benefits

- The isolation of off-line units will bypass the flow of fluid from off-line equipment, resulting in a reduction in energy consumption.
- The switch off of equipment when no cooling load exists (e.g. in the winter months) will reduce low load cycling energy usage and distribution losses.

Technical Requirements

- Technical expertise is required to upgrade and implement this system approach.

Cost & Payback

- The cost and payback will depend upon the existing system and the level of upgrade required.

Risks

- If performed manually, the appropriate staff will need to physically isolate equipment.
- Note that implementation is only applicable to systems in parallel.

Further Information

- hpac.com/air-conditioning/converting-primary-secondary-allvariable-0709/
- www.trane.com/commercial/library/vol31_4/index.asp
- www.arti-research.org/research/completed/finalreports/20070-final1.pdf

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k

Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months

GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

Linkages

- This approach has linkages to most of the Chiller and Cooling measures (HVAC-04 series)

HVAC-04g
Chillers and Cooling — Chiller Retrofit

Benchmarks & Rules Of Thumb

- This measure is appropriate for chillers between 10 and 20 years old. Beyond 20 years in age and replacement should be considered
- Upgrades can result in a chiller energy efficiency up to 30% or more

Introduction

Chillers of ten years or more can be considered for a retrofit focussing on energy efficiency and GHG reductions, and for chillers older than 20 years, replacement may offer a more cost effective solution. The performance of chillers older than 10 years can be enhanced thus increasing the efficiency and reducing energy consumption and costs.

Approach

1. Chiller retrofit is a specialist field where chiller suppliers and manufacturers will need to be consulted. Some of the retrofit measures that could be considered (either collectively or in isolation) include:
    - The addition of variable speed drives to centrifugal chillers;
    - Modernise the controls and add automation to help manage issues such as the limitation of chiller demand, reset chilled water temperature (see HVAC-04d), time of day start/stop mechanism (OPS-03b), optmise load sequencing based on load conditions and identify maintenance needs based on chiller performance.
    - Retrofitting the chiller with a new compressor-motor driveline will maintain the current heat exchanger shells.

Benefits

- Installing VSDs to centrifugal chillers can reduce energy consumption by about 30%, which will reduce energy costs.
- Modern controls can automate functions, hence reducing manual operations functions and this can enhance fine tuning of chiller operation.
- All of the above mentioned retrofits will lead to a reduction of energy consumption and costs.
- Improving chiller efficiency and thus decreasing chiller maintenance and costs.

Technical Requirements

- A qualified chiller specialist or HVAC engineer should undertake chiller retrofits for both installation and feasibility analysis.

Cost & Payback

- Chiller retrofit cost and payback will vary as it will depend on current operational efficiency, electrical tariff structure and energy savings.
- Reductions in annual chiller plant energy costs may be reduced by $20 - $100 per installed ton, depending on climate, application and utility costs.

Risks

- Incorrect installation of any of the above retrofit can lead to malfunctioning of the chiller which cause serious health and safety issues and reduce thermal comfort. It is imperative to ensure that an experienced HVAC engineer undertakes any chiller retrofit work.
- Retain adequate budgets every year to undertake maintenance.

Further Information

- www.energytrust.org/library/case_studies/Rogue_Valley.pdf
- www1.eere.energy.gov/femp/procurement/eep_wc_chillers.html

Linkages

- HVAC-04d Chilled Water Reset (linkage exists between the two reset strategies)
- HVAC-04f Variable Primary Flow (upgrades may be undertaken together)
- OPS-03b Equipment Operation Times (modernising chillers to automation will support start-up time coordination)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
	$10k - 100k
X	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
	<1%
	1 - 5%
X	5 - 10%
	>10%

HVAC-05a
Boilers and Heating — Domestic Hot Water

Benchmarks & Rules Of Thumb

- In office buildings, domestic hot water heating needs can account for 4-5% of electricity consumption or 16% of gas consumption
- Up to 50% of heating for domestic water can be avoided

Introduction

The provision of domestic hot water is a significant energy use due to various factors such as the use of boiler plant being used to satisfy the small load of the domestic hot water (especially in summer months) or the water temperatures being too high. This results in a relatively high energy usage and inefficiency. Re-appraising the domestic hot water needs of the office can help improve energy efficiency.

Approach

1. Assess the current office hot water needs in terms of:
   - The volume consumed;
   - The temperature it is delivered at; and
   - The availability of hot water during the day, and throughout the year.
2. By assessing these, consideration should be given to options to reduce energy requirements including:
   - Not providing hot water in the Summer time to hand basins;
   - Install water flow restrictors and aerators which can help reduce energy;
   - Deliver water at lower temperatures (note that due to health risks such as *Legionella*, optimum temperatures for water storage tanks is 60-65^{o}C, and for instantaneous hot water is 50^{o}C); and
   - Consideration of the time of day hot water is provided.
3. In addition, the heating source of the hot water should be assessed, and where hot water is supplied by a main boiler and/or centralised plant, consider substitution with smaller dedicated water heaters (see HVAC-05c) or the use of solar water heaters (see ESD-05b).
4. The loss of heat through along the system should also be addressed through the proper use of insulation.

Benefits

- Improved energy efficiency.
- Decentralised systems will reduce the pressure drop experienced on domestic hot water distribution networks.

Technical Requirements

- Qualified technicians should be used to adjust and install the water heaters according to the boiler specification.

Cost & Payback

- Making simple changes such as the reduction of water temperature or not providing hot water in summer time will not cost money and can have immediate payback.
- Where the installation of new dedicated water heaters occurs, for a small capital outlay, the benefits can be seen within 12-36 months.

Risks

- Health considerations due to the risk of *Legionella* must be fully appraised.

Further Information

- geoheat.oit.edu/bulletin/bull22-3/art4.pdf
- www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850
- www.carbontrust.co.uk/publications/publicationdetail.htm?productid=CTL032

Linkages

- HVAC-05c Demand Needs (links to the concept of ensuring the heating loads are only provided when needed)
- ESD-04b Renewable Energy (linkage to the use of solar water heating)

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-05b
Boilers and Heating — Boiler Maintenance

Benchmarks & Rules Of Thumb

- Boiler life expectancy is typically 15 to 20 years although poor maintenance can reduce this to less than 10 years
- More than 70% of boiler failures can be linked to poor maintenance
- A comprehensive maintenance program can produce annual savings of up to 5 - 8% of fossil fuel consumption

Introduction

Boilers have a typical life expectancy of 15 to 20 years, however, through a thorough and proper maintenance schedule, this can be increased to 40 years. Regular maintenance and optimisation of the boiler operations can improve boiler efficiency and reduce fossil fuel consumption by typically 5%.

Approach

1. Obtain boiler fuel consumption and demand over a 12 month period and observe performance trends for boiler usage.
2. Obtain boiler O&M manuals and observe manufacturer/supplier maintenance procedures.
3. Obtain boiler maintenance records and operating log sheets.
4. Boiler maintenance should focus on optimising the combustion and boiler house efficiency through minimising excess air and burner tuning.
5. The program developed should typically cover testing, inspection and maintenance of the boiler plant.

Benefits

- Energy savings and financial benefit through peak energy performance.
- Reduced labour cost and associated downtime.
- Equipment lifespan is prolonged.
- Overall installation safety is increased through improved reliability.

Technical Requirements

- Good maintenance requires a proper understanding of the equipment concerned and access to comprehensive performance records. The building managers and facility maintenance staff should be tasked with developing a boiler maintenance program, with input from boiler specialists as required.

Cost & Payback

- The implementation of a comprehensive maintenance program can produce annual savings of up to 5 - 8% of fossil fuel consumption and a reduction in parts replacement costs in most applications.

Risks

- Inadequate knowledge of the appropriate maintenance activities to be undertaken or poor implementation may result in increased boiler running costs, without the listed benefits.

Further Information

- www.chps.net/manual/documents/BPM_2006_Edition/CHPS_IV_2004.pdf
- www.facilitiesnet.com/hvac/article/Boilers-Water-Heaters-Gameplan-for-Energy-Efficiency-Safety--1809

Linkages

- This measure discusses the general approach to boiler maintenance and has direct links to the other HVAC-05 measures.

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not applicable in hot regions where space heating is not used	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-05c
Boilers and Heating — Demand Needs

Benchmarks & Rules Of Thumb

- Understanding heating needs and demand profiles will help to significantly reduce energy costs
- In some cases, the need for heating, such as during Summer times, can be totally eliminated

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not applicable in hot regions where space heating is not used	

Introduction

The operation of installed boiler plant should be matched to the office's requirements, and the seasonal weather fluctuations. Water temperatures should be scheduled against the outside air temperatures and occupation patterns (see HVAC-05d). This should include the use of thermostatic radiator valves (TRV) on radiators. Where multiple boilers exist, they should be managed so that they operate individually at full capacity before the next boiler is bought on-line. Similarly, centralised boiler plant should not be used during periods of low heating loads (normally for hot water or occasionally re-heat as part of a dehumidification system), in order to avoid relatively high energy usage due to the cycling losses and distribution circuit heat loss. Installing a smaller and decentralised heating units for smaller heating loads will improve the overall efficiency and reduce energy consumption.

Approach

1. Determine the seasonal cycles relevant to the office's location and identify periods where external temperatures and conditions where main space heating is not required.
2. Identify during these periods what heating is required such as for domestic hot water or dehumidification.
3. Look at the installation of controls such as TRV and ensure they are properly installed.
4. Review and assess opportunities for alternative heating approaches during these periods including possible decentralisation.
5. Assess the business case for installation.

Benefits

- Reductions in energy costs and financial savings.
- Reduced boiler wear and longer life expectancy.
- Decentralised systems will reduce the pressure drop experienced on domestic hot water distribution networks.

Technical Requirements

- The decision to install alternative and decentralised heating systems will require an analysis of the building load profile by the appropriate building services engineer.
- A technical or certified professional will be required to perform any replacement installations.

Cost & Payback

- Overall cost depends upon the scale and scope of the replacement systems that are needed.
- Changing boiler sequences and temperatures can have immediate payback for no cost.

Risks

- Small modern facilities with new boiler units in service will benefit little from the implementation of this measure. New builds and retrofits of large outdated facilities present the best opportunity for savings.
- If doing a fuel change (e.g. gas to electricity) for hot water provision the high cost of the electricity must be accounted for.

Further Information

- www.viessmann.co.uk/downloads/MediumLargeBoilers.pdf
- www.carbontrust.co.uk/energy/startsaving/tech_heating_upgrading.htm

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-05a Domestic Hot Water (links to the concept of ensuring the heating loads are only provided when needed)
- HVAC-05d Hot Water Reset (again linking to the concept of only heating to the loads needed)

HVAC-05d
Boilers and Heating — Hot Water Reset

Benchmarks & Rules Of Thumb

- Many boiler and hot water systems operate at a standard level, usually dictated by maximum load conditions, meaning energy inefficiency for the majority of the time
- The heating costs of boilers can be reduced by 10% by using hot water reset

Introduction

Boiler and heating set points can often be set for maximum loading requirements, and therefore can be left operating inefficiently above load needs. Implementing a hot water reset strategy where the hot water conditions are linked to the heating needs and external temperatures presents a good energy efficiency opportunity. This approach can be done manually, or for greater savings automatically.

Approach

1. Determine the boiler and heating loads and map against the seasonal cycles relevant to the office's location. The temperature requirements for the heating loads will vary considerably according to the outdoor temperature.
2. A manually operated control programme can be installed where the boiler controls are manually adjusted in response to environmental conditions.
3. For greater savings, automatic controls can be installed which will ensure maximum energy savings. A reset control is a device that automatically controls the boiler water temperature according to a software program based on outdoor temperature.
4. Installing a three-way mixing valve that is controlled by an outside temperature sensor is also an effective way to reset the hot water temperature. The valve mixes return water with the higher water temperatures to reach the desired hot water supply temperature.

Benefits

- Boiler reset improves boiler efficiency and indoor comfort by providing a better match between boiler output and space heating needs.
- Elimination of expensive overheating that is also uncomfortable for building users.

Technical Requirements

- Qualified technicians are required to install the three-way mixing valves and any other controls.

Cost & Payback

- The heating costs of hot water in boilers can be reduced by 10% by using automatic hot water reset and boiler cut-out controls and the payback period is between one to three years.

Risks

- Setting the boiler temperature too low can cause damage to the boiler. Hence it is imperative to check with the boiler manufacturer and maintenance manual for safe temperatures.
- Ensuring hot water temperatures meet minimum temperatures to avoid health risks such as *Legionella* (see HVAC-05a).

Further Information

- www.viessmann.co.uk/downloads/MediumLargeBoilers.pdf
- www.carbontrust.co.uk/energy/startsaving/tech_heating_upgrading.htm
- highperformancehvac.com/HVAC-answers-ac-heating-cooling-ddc/hot-water-boiler-reset-control.html

Applicability

Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not applicable in hot regions where space heating is not used	

Capital Cost (US$)

	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k

Payback

	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months

GHG Reductions

	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- HVAC-05a Domestic Hot Water (links to the concept of ensuring the heating loads are only provided when needed)
- HVAC-05c Demand Needs (again linking to the concept of only heating to the loads needed)

HVAC-05e
Boilers and Heating — Insulation

Benchmarks & Rules Of Thumb

- For insulation materials, the higher the R-value the higher the resistance to heat flow and therefore the better it performs as an insulation material
- Fitting jackets or blankets on hot water cylinders can reduce heat losses by up to 75%

Introduction

Unwanted heat loss through the pipes, tanks, ducts and other equipment in offices can increase heating energy requirements and it will concurrently lead to increased energy consumption and costs. Hence, insulation plays a significant role in reducing heat losses in the HVAC system of an office.

Approach

1. Undertake an insulation audit of the HVAC system to confirm that the "as built" drawings and identify where pipes, tanks and ducts require insulation. Where heat is noted emanating from equipment, this is typically a sign of inadequate insulation.
2. All ductwork should be sealed before insulating it.
3. Undertake an insulation strategy for the office and implement it.

Benefits

- Good engineering design of insulation systems will reduce undesired heat loss or gain by 90%.
- Insulating pipes and ducts will reduce electricity consumption and costs and lead to a decrease of GHG emissions.
- Insulation on hot pipes protects maintenance personnel and prevents condensation on cold pipes.

Technical Requirements

- Technical know how to perform heat loss-gain calculations to evaluate the effects of adding insulation and undertake cost benefit analysis of installing insulation.

Cost & Payback

- The costs and payback will depend upon the extent and nature of required insulation.
- As an example, a 75 mm thick hot water cylinder jacket /geyser blanket will cost about $50 including installation and will save around $70 per year.

Risks

- Insulation can trap moisture which both reduces the R-value and heat retention, produces mould which in turn could lead to structural and health and safety issues.

Further Information

- building.firstlightera.com/EN/Microsites/1/Knauf+Insulation/

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- Insulation applies to all of the HVAC-05 Boilers and Heating measures and also to HVAC-04 Chillers and Cooling
- HVAC-02d Eliminate Ductwork Leaks (cross-over with insulation)
- ENV-08 Insulation (same principles but applied to the building envelope)

HVAC-05f
Boilers and Heating — Flue Shut-Off Damper

Benchmarks & Rules Of Thumb

- Up to 20% of boiler heat is lost in flue gases
- Adding a vent damper can prevent flue/chimney heat losses by up to 4%

Introduction

Boilers must retain a proper flue draft for efficient combustion. Too little draft can result in condensation, carbon monoxide formation, flue gas spillage, and soot formation. Too much draft can result in thermal energy loss from the boiler and higher electrical usage by the vent fan. A vent damper is an automatic device that shuts off the flue gas when the burner is not running, therefore enabling heat to be retained and the boiler efficiency to be improved.

Approach

1. Obtain boiler fuel and maintenance costs and operational schedule.
2. Obtain the existing operational and maintenance manual and logbooks of the boilers
3. Two common types of vent dampers available are electromechanical and thermo-mechanical. The electromechanical vent damper is coupled with the fuel valve while the thermo-mechanical vent dampers open and close according to the temperature rise and fall.
4. Vent dampers are usually installed in the flue pipe between the heating unit and the stack and are also referred to as stack dampers.
5. Select and install based upon advice from heating/boiler experts.

Benefits

- If the boiler is located indoors, up to 11% of the total heating energy can be lost in heating make-up air and in this case, vent dampers can reduce energy costs by 4%.
- The vent damper can prevent heat from being drawn up the warm vent thus prevent thermal heat losses.

Technical Requirements

- Only a qualified technician must undertake the installation and upgrade of flue gas dampers.
- Technical expertise is required to undertake a cost benefit analysis before the flue gas dampers are installed.

Cost & Payback

- Stack dampers cost anything between $200 and $500 excluding installation.
- Research shows that the whole system (including electronic ignition and installation) costs about $1,200 to install for a 400,000 Btu/hr boiler, which achieves a payback of 3.8 years.

Risks

- Though vent dampers are relatively simple devices, very few companies manufacture them and might be challenging to source certified installers.
- Incorrect installation of dampers will lead to a decrease in boiler efficiency thus increase energy costs.

Further Information

- www.stackdampers.com/
- www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12540

Linkages

- This measure has links to the other Boilers & Heating measures of HVAC-05

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not applicable in hot regions where space heating is not used	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-05g
Boilers and Heating — Oxygen Trimming

Benchmarks & Rules Of Thumb

- Boiler efficiency can be increased by 1% for every 15% reduction in excess air or every 4℃ (40℉) reduction in stack temperature
- Applying this approach can typically save 5% of boiler fuel use

Introduction

Inside boilers, air is mixed with the fuel for the combustion process and the combustion efficiency is defined by the air:fuel ratio. To optimise the input fuel usage and for safety purposes, a small amount of additional excess air is provided to ensure that all fuel is completely burned inside the boiler. This air:fuel ratio can however drift due to changes in fuel calorific value, air temperature and wear. In order to decrease stack heat losses and increase combustion efficiency, it is vitally important that only the minimum amount of excess air is injected into the boiler. Oxygen trimming control constantly measures the free oxygen concentration in the boiler.

Approach

1. Compile an inventory of the number of boilers, their locations and their fuel costs.
2. Review the existing operational and maintenance manual and logbooks of the boilers.
3. Increased and unnecessary amounts of excess air can occur because of:
   - Control system defects;
   - Variations in boiler room temperature, pressure, and relative humidity;
   - Lack of burner maintenance; and
   - Variation in fuel composition.
4. Incorporate an oxygen trim system to optimise fuel to air ratio. These systems monitor excess oxygen in the flue gas stack and adjust the air intake to the burners accordingly.
5. Liaise and work with the boiler manufacturer together with the installation of a gas analyser in the stack will optimise and monitor fuel-to-air ratio. Incorporation of a carbon monoxide trim loop together with the gas analyser will ensure that incomplete combustion does not take place due to a lack of air.
6. Installation of a controller should be considered to monitor oxygen in exit gas to optimise excess air.

Benefits

- Oxygen trimming increases combustion efficiency and reduce stack heat losses (see also HVAC-05f).
- Reducing excess air will lead to decreased fuel costs for boilers and a concurrent reduction in energy bills and GHG emissions.

Technical Requirements

- A qualified technician is required to incorporate oxygen and carbon monoxide trim loops or any other control systems.
- Technical expertise is required to undertake a cost benefit analysis before a boiler and its control systems are upgraded/retrofitted.

Cost & Payback

- The cost for incorporating a trim control system is about $10,000 to $20,000.

Risks

- Incorrect integration of oxygen trim loop systems can lead to malfunctioning of the loop resulting in wrong fuel-to-air mixture. This will lead to a reduction boiler efficiency and increase stack heat losses.

Further Information

- www.plantsupport.com/download/CTBB.pdf
- www.energy.wsu.edu/documents/engineering/boiler_comb..pdf

Linkages

- HVAC-05f Flue Shut-Off Damper (links to boiler efficiency)
- HVAC-05b Boiler Maintenance (maintenance is a key consideration for getting the right oxygen:fuel mix)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not applicable in hot regions where space heating is not used	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k

Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months

GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-05h
Boilers and Heating — Economiser

Benchmarks & Rules Of Thumb

- Economisers are usually the best choice for retrofitting very large boilers that operate at significant loads all year round
- A generally accepted "rule of thumb" is that about 5% of a boiler's input capacity can be recovered with a properly sized economiser

Introduction

Boiler stack economisers are simply heat exchangers with hot flue gas on one side and water on the other. Heat that is lost from flue gases can be captured and used through the use of an economiser, therefore improving the boiler efficiency. The application difference between an economiser and condenser is that economisers are primarily used to heat a smaller volume of water to a high temperature for boiler feed water, and condenser units heat a larger volume of water to a lower temperature.

Approach

1. Obtain boiler fuel and maintenance costs and operational schedule.
2. Determine the existing operational and maintenance manual and logbooks of the boilers.
3. Stack economisers recover some of the heat from the flue gases in the stack for pre-heating water.
4. Stack economisers should be considered as an efficiency measure only when large amounts of make-up water are currently used.
5. Economisers must be sized for the volume of flue gas, its temperature, the maximum pressure drop allowed through the stack, the fuel type used in the boiler, and the demand for energy recovery.

Benefits

- Capturing this normally wasted heat reduces the overall fuel requirements for the boiler. Less fuel consumption equates to less costs and fewer greenhouse gas emissions as the boiler would operate at a higher efficiency.
- Economisers can improve fuel efficiency by 3 to 10 percent, depending on the stack-gas temperature from which energy is being recovered.
- Economisers help boilers respond to load changes faster because the feed water entering the boilers is hotter.

Technical Requirements

- Technical expertise is required to undertake a feasibility study and cost benefit analysis before economisers are installed.
- A certified technician should oversee the installation and commissioning of economisers.

Cost & Payback

- The savings potential that can be achieved from an economizer is a function of how much heat can be recovered and how much cold water needs to be heated.
- An economiser that recovers 5% of boiler input will have a maximum of a 3 year pay back period.

Risks

- Ensure that a suitable demand for heat recovered from the flue gases exists. If this is not ascertained, there is a risk of not achieving the savings.
- Flue gas economisers cannot be installed where oil is the primary heating fuel.
- Corrosion of economisers should be managed to avoid risks of oxygen-pitting corrosion and water dew point concerns.

Further Information

- www.stackdampers.com/
- www.peci.org/ftguide/ftg/.../AHU.../ft.../TestEconEvaluation.doc
- www.wellman_robey.com/News/News/Latest/RETRO-FIT_ECONOMISERS/news.aspx?id=425

Linkages

- HVAC-05f Flue Shut-Off Damper (linkage to flue gas controls)
- HVAC-05a Domestic Hot Water (linkage to hot water requirements)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Not applicable in hot regions where space heating is not used	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

HVAC-06
Motors

Benchmarks & Rules Of Thumb

- High-efficiency motors are 2 – 8% more efficient than standard motors
- Conventional motor efficiency ranges from 75 – 88%, while energy-efficient motors are 80 – 95% efficient
- Inverters can reduce energy input by 25 – 50%

Introduction

The high reliability of motors often means they are not the focus of maintenance and cleaning activities. Ensuring appropriate upkeep and cleaning can improve efficiency. When existing motors fail, they are either re-wound or replaced with similar motors. Installing replacement higher efficiency motors will increase replacement costs slightly but offer good energy savings over the life of the new replacement motor. Many motors are often oversized and operate at low loads and lower efficiencies, therefore correct sizing is also important. The possibility also exists to install inverter drives to control the speed of motors in both fixed speed (e.g. remove flow dampers and control using inverter) or variable load applications (e.g. replacing modulating valves and damper controls with inverter variable speed drive control of the main motors) to often give a return on investment within months.

Approach

1. Upkeep and cleaning of motors should be routinely undertaken and include:
    - lubrication of parts such as the bearings;
    - ensuring cooling vents are cleaned regularly; and
    - checking alignment of motor couplings and alignment and tension of belts and pulleys.
2. Replacement—suitable professional advice should be sought to consider:
    - appropriate sizing; and
    - replacement rather than rewind.
3. Consider retrofit options including inverter drives.

Benefits

- Improved energy efficiency and consequent energy savings.
- Reduced heat, vibration and noise levels.
- Reduced maintenance and greater life expectancy.

Technical Requirements

- Replacing existing motors in service with energy-efficient models and inverters, will require the services of a registered electrical professional with experience in installations of this nature.

Cost & Payback

- The cost of energy-efficient motors differs significantly, but typically cost 10 -20% more than standard motors. Payback can be achieved within 1-3 years depending on the working hours and energy costs.
- Variable-speed drives for use on pumps offer a return on investment of between 8 - 24 months, depending on the duty cycle and energy costs.
- Premium efficiency fan and pump motors have the potential to save 35 – 45% on annual investment.

Risks

- The commissioning of inverter drives can be complicated.
- Modified motor couplings and mountings may be required to accommodate the new motors.

Further Information

- www.energy.ca.gov/process/pubs/motors.pdf
- www.energy.wsu.edu/documents/engineering/motors/Prem_motors.pdf
- www1.eere.energy.gov/industry/bestpractices/pdfs/mc-0382.pdf

Linkages

- This measure links to HVAC-02 Air Distribution, HVAC-04 Chillers & Cooling and HVAC-05 Boilers and Heating wherever motors are used

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Annex A.5: Building Envelope (ENV)

The nine measures presented under this section fall under the following main topics:

- Doors and entrances;
- Improvements to glazing/windows;
- Allowing natural ventilation; and
- External Building envelope treatments.

The individual measures can be summarised as follows:

Reference	Measure
ENV-01	Doors and Entrances
ENV-02	Draught-proofing
ENV-03	Window Films
ENV-04	Glazing Options
ENV-05	Natural Ventilation
ENV-06	Solar Shading
ENV-07	Solar Reflective Surfaces
ENV-08	Insulation
ENV-09	Green Roofs

ENV-01
Doors and Entrances

Benchmarks & Rules Of Thumb

- By leaving a door open, up to 50% of HVAC energy costs can be wasted
- Changing single to double glazing in exterior doors can reduce the associated heat loss by 50%

Introduction

Access doors when opened can initiate a wind tunnel effect which can quickly remove any heating or cooling from an office with a significant impact on energy usage. Making a few modifications to integrate secondary doors or draft lobbies can reduce the impact considerably.

Approach

1. Where the UN is a tenant and its offices have direct outside access through main doors, the lease should be reviewed and landlord engaged to determine whether permission would be needed to alter/change doors and entrances.
2. Consideration could be given to installing windbreakers near exterior doors to block prevailing winds.
3. Subject to space constraints, vestibules or revolving doors could be installed at the main building entrance to prevent the infiltration of cold air and drafts. Revolving doors provide an air lock to reduce heating/cooling losses. In smaller offices with doors straight to the outside, door closer mechanisms should be installed.
4. Optimise or minimise use stack effect in high rise buildings depending on the climatic zone of the building.
5. Replacing single glazing with double glazing in doors will cut the door's heat loss in half.
6. Glass or "patio" doors, especially sliding glass doors, lose heat much faster than other types of doors because glass is a very poor insulator. Install a thermal break which is a plastic insulator between inner and outer parts of the metal frames to prevent heat loss .

Benefits

- Reduction in heating and ventilation energy requirements, leading to reduction in energy bills.

Technical Requirements

- Technical know-how to understand the architectural aspects of a building and the savings that can be achieved.

Cost & Payback

- This will vary as the cost and payback will depend on a number of aspects such as geographic location, energy tariff structure and pricing. A cost benefit analysis should be undertaken to determine the return on investment.
- Estimated to cost $10,000 to $25,000 to install a door air lock with no major structural changes.

Risks

- Ensure that the changes to entrances do not compromise security, health and safety, fire and disabled access requirements.

Further Information

- chuck-wright.com/calculators/stack_effect.html
- www.billdoll.com/dir/r/biz/re/hom/imp/ee/hi/wd/wd.html

Linkages

- ENV-02 Draught-proofing (applies to doors and entrances)
- ENV-03 and 04 (measures apply to doors with glazing)
- ENV-05 Natural Ventilation (balance of ventilation versus heating/cooling loss)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

ENV-02
Draught-proofing

Benchmarks & Rules Of Thumb

- Sealing air leaks in offices can reduce energy bills by up to 5%
- Detecting air leaks and gaps can be done manually at low to zero cost

Introduction

Infiltration of external air through gaps in doors, windows and other infrastructure connection points can cause energy losses (heat or cooling escape), therefore it is important that such gaps and openings are appropriately sealed in order to protect the thermal performance of the envelope.

Approach

1. For offices where the UN is a tenant, the lease should be reviewed and landlord engaged to determine whether permission would be needed to undertake draught-proofing.
2. Test for air tightness, which can be done by visual inspection or by room pressurisation which requires sealing of ducts and main doors. Asking occupants/users to report discomfort can also help in identifying leaks/gaps.
3. Use caulk, backer rods, gasketing and weatherstripping to close cracks, openings and gaps.
4. Common areas of air leakage include:
   - Drafty windows and doors, roof or basement doors or hatch.
   - Holes or chases that lead down into the building from the roof and leads up into the building from the basement.
   - Air leaks through gaps around plumbing, electrical penetrations, bathroom and fan vents.
   - Air leaks around recessed lights.
6. Checking and repairing caulk should become part the maintenance plan for the building undertaken every year.
7. Windows, doors, skylights can gain and lose heat in the following ways:
   - Direct conduction through the glass or glazing, frame, and/or door.
   - The radiation of heat into the building (typically from the sun) and out of the building from room-temperature objects, such as people, furniture, and interior walls.
   - Air leakage through and around them.

Benefits

- Reduction in heating and cooling energy requirements that will lead to a reduction in the energy bills.
- Improves occupant comfort.

Technical Requirements

- Expertise to decide on the best sealing technique applicable to the specific building and possibly to help in detecting leaks.

Cost & Payback

- Typical savings of 1-5% or more can be achieved on energy bills by reducing the air leaks in offices.
- Costs and payback depend upon scale of office.

Risks

- Some types of caulk shrink over time and hence might have to be redone every two years or so.

Further Information

- www.engext.ksu.edu/henergy/envelope/airsealing.pdf

Linkages

- ENV-01 Doors & Entrances (links to doors)
- ENV-03 and ENV-04 (relevance to windows and glazing)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

ENV-03
Window Films

Benchmarks & Rules Of Thumb

- Window films can reduce solar heat gain by up to 40 - 80%
- Window films can restrict 95 - 99% of UV rays, and transmit 75% of the total incident sunlight

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
More suitable to hot climates	

Introduction

Films can be applied to the windows of offices to allow a reduction in solar heat gain yet still allowing the infiltration of daylight. This can be a particularly effective measure in climates and seasons with strong sun.

Approach

1. For offices where the UN is a tenant, the lease should be reviewed and landlord engaged to determine whether permission would be granted for installing window films.
2. Understand local climate and solar data, the office's orientation and how/when direct sunlight shines on windows.
3. Determine the existing window and physical fenestration specifications.
4. Research and investigate solar film suppliers and work with them to define the appropriate specification to suit the office's needs.
5. It may be necessary to evaluate whether particular window surfaces are well-suited to, and will benefit sufficiently from, the installation of films, by virtue of either location or physical construction.

Benefits

- A reduction in building heat gain can provide energy and financial savings through reduced heat transfer and decreased energy usage on cooling.
- Reduces hot spots and glare, consequently increasing occupant comfort.
- Certain window films may be designed to provide additional safety features, in the event of crime or adverse weather conditions.
- Office content is protected from sun-induced damage.
- Absorptive films will reduce the building heat load during winter months.

Technical Requirements

- It is recommended that installation be performed by a representative of the manufacturer.

Cost & Payback

- Payback can be achieved within 6 months in certain applications, however 2 to 5 years are typically required to recover the initial cost.

Risks

- Films are a permanent feature and cannot be added and removed as required, and may produce low light conditions during periods of little solar irradiation.
- Films may produce external glare.
- The lifespan of window films is not infinite. Films may tear or scratch if the necessary care isn't taken and may require replacement after 10 years in service for indoor applications, or 2 to 3 years externally.
- Poor installation may significantly reduce the life expectancy.

Further Information

- solutions.3m.com/wps/portal/3M/en_US/WF/3MWindowFilms/Solutions/Residential/

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- ENV-04 Glazing Options (the type of glazing may mean films are not necessary)
- LIG-03 Daylighting (linkage to daylighting and glare control)

ENV-04
Glazing Options

Benchmarks & Rules Of Thumb

- 20-25% of heat in buildings is lost through single glazed windows
- The ideal window will have a high R-value (trending to 3), a low U-value (nearer to 0), a high VT-value (trending to 1) and be low-e

Introduction

Single glazed windows can result in substantial energy losses due to the lack of thermal insulation they provide. The upgrading of windows to double or triple glazing can help minimise heat losses, and can also be link with draught-proofing (ENV-02) and window films (ENV-03). Changing the window framing can also reduce heat loss/gain and further improve the window unit efficiency.

Approach

1. For offices where the UN is a tenant, the lease should be reviewed and landlord engaged to determine whether permission would be granted for window upgrades.
2. Compile a list of the number of windows in the office per floor and room, including their current form of glazing, their condition and their orientation. Single glazed windows should be considered for upgrading, as well as windows which are subjected to strong sunlight at certain times of the day and year. The weather patterns should be an important consideration.
3. Undertake cost benefit analysis to replace identified existing windows with double/triple glazed windows. Windows should be chosen based upon their insulation (R-value) and heat transfer (U-value) properties, visible light transmittance (VT) and emissivity.
4. If full window replacement is not viable or practical, consider the installation of secondary glazing, which will not affect the structural integrity of the main windows, or the use of DIY insulation films.
5. As well as the glazing, other considerations include the air leakage (AL) of the window unit (the lower the better) and the window frame materials, where fibreglass, vinyl or wood should be chosen over aluminium/metal frames.

Benefits

- Double glazing or double glazed windows prevent heat losses hence reducing required cooling energy. This leads to a decrease in cooling energy requirement, concurrently decrease in energy bills and GHG emissions.
- Maintains the room temperature, thus enhancing thermal comfort for building users and conserves energy.

Technical Requirements

- Expertise to undertake cost benefit analysis of upgrading the glazing for identified windows and to decide which type of glazing to be implemented.
- Qualified technicians are required to replace existing windows.

Cost & Payback

- An energy manager should undertake energy cost benefit analysis from efficient glazing's, because the glazing will impact both HVAC and lighting loads, and the lighting loads also affect the HVAC loads.
- Installed costs of window glazing can $10 to $20 per m^2 and it will depend on the type and quality of glazing chosen. Secondary glazing can cost as little as $1-2 per m^2. Paybacks are typically of the order of 3 years.

Risks

- Older buildings may have heritage restrictions affecting window upgrades.

Further Information

- www.house-energy.com/Windows/Payback-Windows.htm
- www.efficientwindows.org
- www1.eere.energy.gov.consumer/tips/windows.html
- www.basix.nsw.gov.au

Linkages

- ENV-03 Window Films (choose one approach of the other)
- ENV-07 Insulation (cross-reference to window frames)
- LIG-03 Daylighting (linkage to maximizing daylight)

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

ENV-05
Natural Ventilation

Benchmarks & Rules Of Thumb

- Use of natural ventilation is generally limited to only temperate climates with moderate humidity
- If using natural ventilation, ensure that the mechanical systems are switched off

Introduction

Using natural ventilation, as opposed to mechanical cooling, represents an energy efficient way of improving the internal office conditions. The aim is to use ventilation corridors inside the office to provide open pathways for external air (typically cooler and drier) to replace warmer and humid indoor air. Natural ventilation may also be supplemented by use of electric fans and mixed-mode cooling, which use electricity, but far less than as for total mechanical cooling. The measure discussed will be in the context of existing office buildings.

Approach

1. Have a good understanding of the existing natural ventilation scheme in the office including:
    - the façade type and depth of floor plate (some offices will not be suitable).
    - room layouts, current open pathways for air, and external openings such as windows, louvers and doors.
    - external features such as landscaping and weather patterns.
2. Implementing an effective approach to natural ventilation will be office-specific based upon the base building, office layout and surroundings. Some useful considerations include:
    - ensuring unobstructed ventilation corridors.
    - ensuring sufficient external openings such as windows and doors.
    - ensuring the active participation of the office occupants.
    - external ambient air conditions (to determine what time of day and year natural ventilation could be used).
    - external factors such as shading and vegetation (to direct winds).
    - factors which may negatively affect the use of natural ventilation such as external noise or pollution.
3. Ensure that mechanical systems are switched off when natural ventilation is being used.

Benefits

- Using natural ventilation will reduce cooling energy that will concurrently lead to a reduction in energy bills and greenhouse gas emissions.
- The use of natural ventilation will improve building occupant comfort.

Technical Requirements

- The use of natural ventilation scheme should be matched to the office's HVAC requirements and the seasonal weather fluctuations. This measure will depend on the balancing of a few of the measures mentioned in this section such as the use of passive solar, daylighting, sun shading, and landscaping strategies.

Cost & Payback

- This will depend entirely on the office and hence a cost benefit analysis should be undertaken to implement the use of natural ventilation mechanisms. However, if the office is capable of supporting natural ventilation, it is a low cost and quick payback solution.

Risks

- If the use of natural ventilation strategies is not carefully modeled, the desired thermal objectives might not be achieved.

Further Information

- www.ihea.com.au/energy/repository/dhs/AN-NV.pdf
- www.ncdc.noaa.gov/oa/ncdc.html
- www.eere.energy.gov/buildings/high_performance

Linkages

- This measure links to all other measures in that it is finding a balance between the required thermal comfort settings (OPS-02) and the external conditions to reduce required heating and cooling
- HVAC-03 Air Economiser (which is a form of natural ventilation)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Unlikely to be applicable in hot and humid climates	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
X	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

ENV-06
Solar Shading

Benchmarks & Rules Of Thumb

- Closing blinds can save between 5 and 30% of cooling energy needed to offset solar gain
- Installing external solar shades can reduce internal mechanical cooling needs by up to 5%

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

Solar shading, both internal and external, provides a valuable benefit in terms of reducing solar heat gain and hence reduces the office's air conditioning load. It can also be an important consideration for occupant comfort in terms of reducing glare.

Approach

1. Understand the specific solar angles and intensities throughout the year applicable to the office's location.
2. Restricting direct sunlight into a building is the most effective manner in which to inhibit solar heat gain, whether by internal or external means.
3. Internal measures include the use of internal blinds or curtains and are applicable to all offices.
4. External shading requirements, which will depend upon the level of control the UN has for the office, may comprise one or a combination of the following:
    - External louvres, overhangs and awnings.
    - Shutters, external roller blinds and even vegetation may all classify as forms of solar shading.
    - Conversion of some windows to insulated spandrels.
5. The colour of the materials is also important to maximise reflectance.

Benefits

- Results in energy savings through reduced heat gain and an associated reduced cooling load. Life-cycle costs are improved as a result.
- While shade is provided during summer, some devices permit the entry of lower angle winter solar radiation.
- Lighting levels within the building become more uniform and glare is decreased, improving occupant comfort.

Technical Requirements

- A suitably qualified person will have to establish the nature and position of the recommended shading devices. The installation of most fittings does not require any particular expertise.
- Active solar shading devices may be linked to a Building Management System (see HVAC-02) that open or close electronically according to the position of the sun. The technical requirements associated with such a system are likely to be significant.

Cost & Payback

- Payback will depend to a large degree on the office and shading device characteristics. Example costs are \$100+ per m^2 for interior blinds, and \$200 to \$1,000 per m^2 for external sun shading.

Risks

- There are no direct risks associated with solar shading technology.
- Incorrect installation leads to inappropriate light levels and is costly to remedy. Finding the right balance between the shading requirements and still ensuring maximum daylight is a balance.

Further Information

- windows.lbl.gov/daylighting/designguide/section5.pdf
- www.nrc-cnrc.gc.ca/eng/ibp/irc/cbd/building-digest-59.html

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

Linkages

- ENV-03 and 04 (solar shading based upon glazing properties)
- ENV-07 Solar Reflective Surfaces (further reducing heat gain)
- ENV-08 and 09 (further reducing heat gain

ENV-07
Solar Reflective Surfaces

Benchmarks & Rules Of Thumb

- Cool roof systems with high reflectance and emissivity can reduce the surface temperature of conventional roof materials by almost 40℃
- Raising the roof reflectivity to 0.6 can bring about energy savings in excess of 20%

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Introduction

In hot climates, dark non-reflective roofs absorb energy from sunlight, and as a result increase office heating and the need for mechanical cooling. In addition, such roofs contribute to the heat island effect, which artificially elevates the temperatures of urban areas, thus increasing cooling needs. The use of solar reflective surfaces, whether as a reflective skin or through painting of existing roof systems with reflective paint systems., can reduce these effects. In cold climates, the reverse is true and the use of heat absorbing materials may be desirable to reduce heating demands.

Approach

1. For offices where the UN is a tenant, the lease should be reviewed and landlord engaged to determine whether permission would be granted for this measure, or whether the landlord will implement it.
2. Determine the annual office temperature profile and electricity consumption and compare with the local climate trends (cooling and heating degree days).
3. Determine the existing roof materials and their solar reflectivity.
4. It may be necessary to evaluate whether particular roofing surfaces are physically suitable for repainting, or whether complete replacement would be preferred.
5. Consider the solar reflective roof solution to be applied such as membrane coating, paint or roof gardens (see ENV-09).

Benefits

- A reduction in office heat gain can provide energy and financial savings through decreased energy usage on cooling, and in colder climates increasing heat gain will reduce heating needs.
- Increased indoor comfort for office occupants.
- A decrease in the urban heat island effect.

Technical Requirements

- Evaluate whether roof surfaces can be repainted with a white, water-based acrylic polymer, which requires little expertise. If complete replacement is preferred, the services of an experienced professional will be required.

Cost & Payback

- The cost of a repainted a roof will be significantly less than a retrofit, with material and labour costs recovered in a short period of time.

Risks

- A white roof will absorb less heat during winter months which will result in increased heating costs, however the savings on cooling energy are likely to outweigh that spent on heating.
- The use of white roofing on sloped surfaces may result in excessive glare for neighbouring buildings, while poorly positioned white roofs may redirect glare into the upper floors of multi-storey buildings.

Further Information

- www.greenproducts.net/green_building/EDR-Issue24-Jan19.pdf
- eetd.lbl.gov/coolroof/
- www.coolroofs.org
- www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products
- www.energystar.gov/ia/partners/product_specs/eligibility/roofs_elig.pdf

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- ENV-06 Solar Shading (will be complimentary)
- ENV-09 Green Roofs (presents an alternative option)
- ENV-04 Glazing Options (presents solar reflective considerations for glazing)

ENV-08
Insulation

Benchmarks & Rules Of Thumb

- The higher the R-value of insulation, the higher the resistance to heat flow
- Buildings traditionally lose 25% of their heat through the roof, and can lose up to 35% through walls in certain climatic conditions
- Feeling internal walls, roofs or floors gives a quick indication of insulation effectiveness

Introduction

Unwanted heat loss or gain through walls and roofs can increase energy consumption and costs significantly, and hence thermal insulation plays a significant role in improving comfort levels in offices as well as reducing energy costs. In hot climates, insulation is often ignored but can be equally as important for retaining cooled air.

Approach

1. Compile an inventory of current insulation types and where they are located in the office.
2. Compile an inventory of the equipment space that requires insulation, and link with 1. above. A rough indication is to feel the temperature of a ceiling/roof, wall or floor on a hot or cold day. If the surface feels much warmer or colder than the inside air, then take a look at the insulation to determine whether it is sufficient.
3. Gather climatic condition data such as heating degree days (HDD) and cooling degree days (CDD).
4. Undertake an insulation audit of the office and undertake the implementation of an insulation strategy for the office, which should consider the following:
   - Insulation of the ceiling spaces and roofs
   - Insulation of walls and spandrel panels
   - Insulation of floors above unconditioned space or car-park areas
   - Replacement of thermal bridges such as metal window frames.
5. Assess the right type of insulation needed including its performance (R-value).

Benefits

- Thermal insulation will reduce electricity consumption and costs and lead to decrease GHG emissions.
- Roof and wall insulation both serve the purpose of retaining heat (or cooled air) within the building envelope by reducing the conductivity of the respective surfaces.
- Roof and wall insulation assist in diffusing ambient noise.

Technical Requirements

- Technical know how to perform heat loss-gain calculations to evaluate the effects of adding insulation, to calculate the benefits of different levels of insulation and to implement cost effective insulation opportunities.
- The installation of layered thermal insulation in ceilings can be performed by building owners or skilled professionals, while the use of professional services is preferred for injected cavity wall insulation.

Cost & Payback

- Payback on insulated ceilings and walls can often be achieved within 1- 3 years, particularly if the DIY option is selected. Expected lifespan may exceed 20 years.

Risks

- Choosing an insulation material and installing it correctly is critical to undertaking the insulation strategy.
- Insulation can trap moisture, which both reduces heat retention and produces mould. Mildew has been linked to several health problems.

Further Information

- www.whi.ie/geothermal.htm
- www.building-insulation.com/

Linkages

- ENV-09 Green Roofs (alternative form of insulation)
- ENV-01, 02, 03, 04, 06 and 07 (complimentary to insulation approaches)
- HVAC-05 Insulation (same principles applied but to specific systems/equipment)

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

ENV-09
Green Roofs

Benchmarks & Rules Of Thumb

- On average, green roof temperatures are up to 30^{o}C cooler at the surface and 18^{o}C cooler inside than conventional tar-based black-top roofs
- Using a green roof could save up to 20% on air conditioning costs

Introduction

Whilst green roofs provide an amenity value to offices and buildings, they can also play an important role in energy efficiency through providing an insulation layer and preventing excessive solar gain.

Approach

1. For offices where the UN is a tenant, the lease should be reviewed and landlord engaged to determine whether permission would be granted for this measure, or whether the landlord will implement it.
2. Identify possible roof areas suitable for green roofs. A structural evaluation will be required to determine whether a building will be able to support the additional green roof load.
3. If a green roof solution is to be considered, expertise should be sought in terms of the design based upon the amenity and energy efficiency requirements. Key considerations should include:
    - the local climate and what vegetation this can support.
    - the vegetation to be used (e.g. grasses, shrubs etc.)
    - the depth of soil.
    - the irrigation and drainage needs.
    - associated maintenance requirements.

Benefits

- Soil is a very good thermal insulator and will reduce the transfer of heat from a heated roofing surface through to the enclosure and ultimately the occupants. The presence of vegetation further reduces the surface temperature of the roof. A green roof also insulates a building from thermal losses during winter months.
- Evapotranspiration will result in local cooling and temperature regulation, combating the urban heat island effect.
- Dampens noise, recycles carbon and absorbs airborne contaminants and dust.
- Urban storm water runoff is decreased.

Technical Requirements

- Expertise will be needed for the design and construction of green roofs.
- Provision will need to be made for roof access and watering of the green roof during the dry season.

Cost & Payback

- The cost of a green roof is generally 10-15% more than that of a conventional roof, while the associated savings will be highly climate specific. An installed green roof with a root repellent / waterproof membrane will cost between $1 - 2.5 / m^2.

Risks

- Ensuring that structurally an office/building can take the loading of a green roof.
- Green roofs may increase the risk of dampness if poorly installed, which could threaten structural stability.
- A degree of maintenance will be required, roof access for this purpose may result in an increased risk to human safety.

Further Information

- www.greenroofs.com/Greenroofs101/economic.htm
- www.wbdg.org/design/resource.php?cn=o&rp=41

Linkages

- ENV-08 Insulation (Green roofs provide insulation)
- ENV-07 Solar Reflective Surfaces (green roofs have this effect)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Annex A.6: Office Equipment (OFF)

The four measures presented under this section fall under the following main topics:

- Equipment stand-by;
- Centralisation of equipment;
- Selection and purchase of energy efficient equipment; and
- Server rooms.

The individual measures can be summarised as follows:

Reference	Measure
OFF-01	Equipment Settings
OFF-02	Equipment Centralisation
OFF-03	Energy Efficient Equipment
OFF-04	Server Rooms

OFF-01
Equipment Settings

Benchmarks & Rules Of Thumb

- For anywhere between 20-80% of the time, office equipment is not being used
- Estimates suggest that 80% of printers used in offices, 70% of copiers, and 30% of computer monitors are left on overnight
- Enabling a computer's power management features allows powering down to about 15% of its full power

Introduction

On average, office equipment is not being used for between 20-80% of the time. Although individually small plug-in equipment has a low energy usage, when all installed equipment in an office space is added together, the power consumption can be large. Establishing a combination of manual and automatic procedures for powering down, putting on stand-by and switching off these items of equipment will result in a significant annual power reduction for a site.

Approach

1. Determine existing switching arrangements through discussion with facilities and office staff.
2. Ensure that all auxiliary equipment is energy compliant and where possible includes off switches rather than standby modes.
3. Switch off equipment during non-working hours either by manual shut down or by standby power down.
4. Increase awareness of employees to efficiently use and reduce operating hours of auxiliary equipment.
5. Determine if smart power strips are cost effective to install. If it is, plug all office equipment into occupancy sensor power strip that can turn off equipment if employees leave the room for more than a few minutes.
6. Establish standard default settings for all equipment such as:
   - use of screensavers and timings of stand-by activation.
   - computer screen brightness levels.
   - power-down timings and automatic switch-off times.
7. Ensure that all equipment is maintained and if faults are identified, corrective actions are taken.
8. Many employees have individual extra heaters, fans, humidifiers or air filters. This extra equipment consumes significant amount of energy and are signs of problematic ventilation systems. Undertake a walk through audit to determine if employees use this type of equipment.

Benefits

- Reduces energy consumption and costs.
- Reduction and efficient use of auxiliary equipment will lead to a reduction in energy consumption and concurrently to a reduction in energy bills.

Technical Requirements

- Technical know-how to set equipment energy saving features.

Cost & Payback

- Switching off equipment during the night has a zero cost and immediate payback.
- Occupancy power strips are approximately $20 to $50 more expensive than regular power strips. The payback of installing an occupancy sensor will be less than a year if equipment is currently operational during the night.

Risks

- Incorrect choice of power strips for the office area might also lead to untimely shutdowns as some strips are more prone to false triggering than others.

Further Information

- www.peoplesgasdelivery.com/business/DisplayESource.aspx?type=PA&page=PA_3
- www.accenv.com/documents/EnergyMeasuresforTenants.pdf
- www.doa.state.wi.us/docs_view2.asp?docid=6147
- www.energysmartallies.com/esa/tips.html#buildings

Linkages

- OFF-03 Energy Efficient Equipment (many of these models have specific power down and energy saving stand-by modes)
- OFF-02 Equipment Centralisation (can allow stand-by functions to be set-up centrally)

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

OFF-02
Equipment Centralisation

Benchmarks & Rules Of Thumb

- Centralisation and networking can enable a reduction in the numbers of equipment items needed such as printers
- In larger offices, it centralisation of equipment can also enable focussed cooling

Introduction

The centralisation and networking of office equipment can assist in energy and GHG reduction in a number of ways including reducing the number of equipment items within an office, controlling operational times and stand-by modes (see OFF-01), minimising excessive use and centralising cooling requirements.

Approach

1. Compile an inventory of all equipment than can be connected to the local network such as printers, scanners, copiers and computers.
2. Consult the IT manager (or external IT support) and obtain a quote to implement local area network (LAN) connected systems rather than each employee having their own equipment.
3. Install a LAN system to connect one or two copiers and printers that are centrally located in “islands” on each floor to cater for all printing and copying needs of the employees.
4. Ensure that all IT and computing equipment is of the most energy efficient type and that they have automatic shut down or sleep modes.
5. When replacing equipment, purchase equipment with a seven-day clock that allows programming to allow the equipment to be turned off at the end of each work day and on weekends.
6. In larger offices, where dedicated copier and printing rooms are established, localised cooling requirements can be delivered to these rooms rather than general office cooling to compensate.

Benefits

- Reduce air conditioning requirements to cool down the heat produced by the equipment.
- Reduce energy consumption that concurrently leads to reduce in the carbon footprint.
- This will enhance the mobility of employees to be able to work from different locations which in turn may have carbon implications.

Technical Requirements

- Technical know-how to understand the LAN requirements and functionality of equipments.
- Expertise to install LAN systems, cables and their support infrastructure.
- Might have to negotiate a new IT contract to increase the IT support.

Cost & Payback

- The cost of installing a LAN system will vary as it will depend on the existing system and infrastructure.
- A feasibility study should be undertaken to investigate the business case of implementing a LAN system.

Risks

- Ensuring that confidentiality issues are managed where communal facilities are established.

Further Information

- www.cisco.com/web/about/ciscoitatwork/business_of_it/connected_workplace_web.html
- www.energyrating.gov.au/library/pubs/greenofficeguide.pdf

Applicability	
Office Scale & Situation:	
X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
X	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Linkages

- OFF-01 Equipment Stand-by (the networking and centralisation will allow central set-up of a number of these functions)
- OFF-03 Energy Efficient Equipment (as part of the centralisation process, consideration should be given to energy efficient equipment)

OFF-03
Energy Efficient Equipment

Benchmarks & Rules Of Thumb

- Office equipment can account for 30% of a tenant's energy use
- Between 20-80% of equipment energy use occurs when it is in stand-by mode
- Computers and monitors account for up to 85-90% of an office's equipment costs
- To estimate the energy cost of equipment including cooling needs, use a 1.3 multiplier

Introduction

There are various labelling and performance schemes that promote energy efficiency in office and plug-in equipment. Establishing procurement policies that promote the purchase of energy efficient new and replacement offers an opportunity for GHG emission reduction from the organisation's office. The significance of office equipment in terms of annual spend and associated energy costs makes this a key priority.

Approach

1. Compile an inventory of all equipment in the office.
2. Research the relevant energy efficiency labelling schemes that may be relevant to the country of the office, and if no local scheme exists, assess available international standards e.g. Energy Star. In addition, determine the energy consumption of the equipment when in use and in stand-by (in either watts or kWh).
3. Implement "the buying of only energy certified compliant product" as a policy into the procurement process of the organisation, and as part of the maintenance and replacement programme.
4. Ensure all energy saving modes are being used – and in the case of computing and printing equipment, it may be possible to make these changes across the network (see OFF-01).
5. Also look at equipment substitution such as laptops over standard computers (up to 90% more energy efficient), and use of LED screens over monitors (again up to 90% energy savings).

Benefits

- Reduction in energy consumption will occur by using more efficient appliances.
- Less space is needed, e.g. when converting from old computer monitors to more efficient flat-screens.
- More energy efficient equipment means less heat generation which in turn reduces cooling energy needs.

Technical Requirements

- No specific expertise is needed, however awareness will need to be built within the organisation to promote buying energy certification compliant equipment.

Cost & Payback

- The cost difference between normal appliances and energy efficient appliances will vary and payback will depend on the accumulative savings that can be achieved through the efficiency of the various equipment.
- The energy cost savings will differ from office to office as the energy pricing and tariff structure is also different.
- In general, payback can be within 12 months for the uplift cost of energy efficient equipment.

Risks

- None identified.

Further Information

- www.energy.wsu.edu/documents/building/res/Eff_appliances.pdf
- www.eia.doe.gov/emeu/efficiency/appliance_standards.html
- www.energystar.gov/
- www.eu-energystar.org/en/en_database.htm
- www.energystar.gov.au
- www.unep.fr/scp/sun (SUN product fact sheet on sustainable procurement of IT equipment)

Linkages

- OFF-01 Equipment Stand-By (often many of the newer energy efficiency models have low energy stand-by functions)
- OFF-04 Server Rooms (linkage to the server rooms where computing equipment purchased should meet energy efficiency standards)

Applicability

Office Scale & Situation:

X	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership

Climate Zones:

Applicable to all climate zones

Capital Cost (US$)

	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k

Payback

	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months

GHG Reductions

	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

OFF-04
Server Rooms

Benchmarks & Rules Of Thumb

- Server rooms and data centres are often one of the main energy consumers in an office
- 50% or more of server energy consumption goes on cooling
- Energy savings of between 25-50% can be achieved through efficient energy and cooling management

Introduction

Server rooms and datacentres are often the largest energy consumers within offices through both server demand and then the subsequent cooling needs to counteract the server heat dissipation. Server room and data centres therefore offer significant opportunities for energy improvements and efficiencies, and GHG reductions.

Approach

1. Compile an inventory of the equipment load in the server room and the rated power consumption. Determine if the server room is sub-metered and if not seek to implement (see ESD-02b).
2. There are many different configurations and approaches to server room and data centre set-up, and hence numerous energy reduction opportunities. The following provide a few key initiatives to be considered:

   Servers and racks, and server room:

   - Locate server room away from high temperature rooms, and ensure doors are always closed;
   - Ensure servers are turned off when not in use and apply effective power management;
   - Server virtualisation and rack consolidation to reduce the number of servers needed;
   - Remove all equipment that does not require cooling out of the server room; and
   - Provide overhead cabling to reduce heat gain and reduce airflow restrictions.

   Cooling strategies and measures:

   - Incorporate outside air or water economiser strategies (see HVAC-03 for air and HVAC-04c for water);
   - Supply air reset coupled with rack temperature sensing to maximise supply air temperature;
   - Cooling air delivery should be at floor level and located close to where it is needed;
   - Challenge the operating temperatures in the server room and seek to raise them; and
   - Install energy efficient lighting (LIG-04a), minimise lighting levels (LIG-01b) where possible and use occupancy sensors (LIG-02), therefore reducing any lighting cooling loads.

Benefits

- Reduction in energy consumption and GHG emissions.

Technical Requirements

- Technical know-how to understand the temperature requirements of IT equipment in the server room.

Cost & Payback

- There are many measures that can be applied for no cost with immediate payback.
- The payback of other initiatives will depend on the actual measures proposed.

Risks

- Ensuring that any energy management measures do not compromise the reliability of the server operations.

Further Information

- www.42u.com/measurement/pue-dcie.htm http://www.doa.state.wi.us/docs_view2.asp?docid=6147
- www.thegreengrid.org/

Linkages

- ESD-02b Submetering (submetering is encouraged for server rooms and datacenters)
- HVAC-03 and HVAC-04c (for outside air and water economiser strategies)
- LIG-01b, 02 and 04a (for energy efficient lighting strategies)
- OFF-03 Energy Efficient Equipment (standards for computing and other equipment)

Applicability	
Office Scale & Situation:	
	All Organisations
X	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
X	No cost
	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
X	Instant
	<6 months
	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
	<1%
X	1 - 5%
	5 - 10%
	>10%

Annex A.7: GHG Compounds and Refrigerants (REF)

The two measures presented under this section fall under the following main topics:

- GHG compound management; and
- Replacement of GHG-containing equipment.

The individual measures can be summarised as follows:

Reference	Measure
REF-01	GHG Compound Management
REF-02	Replacement of GHG Containing Equipment

REF-01
GHG Compound Management

Benchmarks & Rules Of Thumb

- About 75% of installed cooling equipment may have incorrect amounts of refrigerant
- Incorrect refrigerant level can lower efficiency by 5 to 20%
- An indication of refrigerant loss is if the equipment produces abnormal noises, vibration and ice formation or insufficient cooling capacity

Introduction

Maintaining correct refrigerant charge levels is important to ensure that equipment runs effectively with the lowest energy use to perform the required duty and to minimise premature equipment failure. This approach also ensures that the potential leakage or escape of GHG compounds is being assessed and checked so that remedial action can be taken if necessary.

Approach

1. Compile an inventory of all equipment using greenhouse gases (GHG) such as air conditioning units, chillers and fire suppression systems, and the type of GHG present in the equipment. Specifically, an inventory of refrigerant containing equipment, and the types and quantities of refrigerants should also be developed and maintained.
2. Ensure that the maintenance requirements of the equipment is being followed, which will likely require the use of an external contractor. For refrigerant-containing equipment, a contractor will use one of three methods, recommended by equipment manufacturers, to verify the correct refrigerant level. These methods include super-heating, sub-cooling, or weighing.
3. The refrigeration equipment should also be tested for pressure and leaks.
4. Analysis of the contractor's logs and records will give an indication of the amounts of recharging necessary for items of equipment, and this will also give an indication of potential leakage and loss.
5. Air trapped in the refrigerant loop increases pressure at the compressor discharge, and therefore increases the work. Therefore purge air from refrigerant. Daily or weekly tracking will show if a leak has developed that allows air into the system.
6. Leak tests are normally conducted after a repair is complete.
7. GHG compounds that are removed from the equipment should be captured and recycled through certified recyclers.

Benefits

- Reducing the GHG footprint of the organisation.
- Minimising leaks and ensuring correct charge levels increases efficiency of the refrigeration equipment.

Technical Requirements

- Technical know-how to understand the system design, operation and performance of the refrigeration and GHG-containing equipment.
- Expertise to inspect and identify any potential area where leak may occur.

Cost & Payback

- The cost for checking charge levels should be included in the maintenance plan and therefore should be a minor cost item. Where repairs are needed, the cost and potential payback will vary.

Risks

- If leaks are not fixed properly and if the correct charge levels are not resolved, further degradation of efficiency can occur.

Further Information

- www.environ.ie/en/Publications/Environment/Atmosphere/FileDownLoad,20047,en.pdf
- www.undp.org/chemicals/montrealprotocol.htm
- www.epa.gov/greenchill/downloads/LeakGuidelines.pdf

Linkages

- REF-02 GHG Replacement of GHG Containing Equipment (next step if equipment of GHG compound replacement is considered)
- HVAC-04b Chiller Maintenance (ensuring the correct refrigerant level in chillers is crucial)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
X	$0 - 10k
	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
X	6 - 12 months
	12 - 24 months
	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

REF-02
Replacement of GHG Containing Equipment

Benchmarks & Rules Of Thumb

- Many synthetic refrigerants and GHG compounds have ozone depleting potential and global warming potential many orders of magnitude greater than carbon dioxide, meaning only a tiny leak or release can have a large impact in terms of equivalent GHG emissions

Introduction

Various equipment in offices can contain GHG compounds such as refrigerants in air conditioning and chillers and fluorinated gases in fire protection systems. Different refrigerants can have varying performance that can affect the efficiency of the refrigeration process and hence increase energy consumption. In addition, many refrigerants, especially chlorofluorocarbons (CFCs) have powerful global warming potential (GWP) and ozone depleting potential (ODP), making them harmful compounds to the environment. Seeking to replace inefficient refrigeration equipment as it fails, and in some instances actually replace the refrigerants themselves, can contribute both to energy efficiency and to GHG reductions. Similarly, replacement of fluorinated gases in fire protection equipment also has distinct GHG reduction advantages.

Approach

1. Compile an inventory of all equipment using greenhouse gases (GHG) such as chillers, fire hydrants and refrigerators and the type of GHG present in the equipment, and its associated GWP and ODP.
2. Research for alternatives to replace the current equipment containing GHG compounds, or in limited cases the actual compounds themselves (such as for R11 chillers), based upon improved refrigerant performance, lower GWP and ODP.
3. Research of any regional/federal programs for replacement of GHG compounds.
4. Suppliers and manufacturers will need to be consulted for direct GHG compound replacement considerations.
5. Update procurement policies and processes to reflect findings, and implement replacement as part of office maintenance and replacement procedures.
6. Wherever equipment is replaced, or GHG compounds are substituted, ensure that appropriate gas capture and disposal routes are followed to prevent leakage and release of the compounds.

Benefits

- Replacement of compounds with reduced GWP and ODP will overall reduce the GHG profile of the office.
- Replacement of refrigerant will improve performance and lead to less energy consumed and hence reduce energy bills.

Technical Requirements

- Technical know-how and understanding of GHG compound and refrigerant containing equipment is required.
- Ensure that certified technicians undertake the replacement of refrigerants.

Cost & Payback

- This will vary, so a feasibility study should be undertaken before any refrigerants are replaced. In many cases there may not be a financial payback.

Risks

- HFCs are more expensive refrigerants than HCFCs.
- The reduction of emissions from equipment is critically dependent on correct installation and servicing, and subsequent management and decommissioning.

Further Information

- www.environ.ie/en/Publications/Environment/Atmosphere/FileDownLoad,20047,en.pdf
- www.refex.com/
- www.epa.gov/ozone/strathome.html
- www.undp.org/chemicals/montrealprotocol.htm

Linkages

- REF-01 GHG Compound Management (linkage to the appropriate management of GHG and refrigerant compounds in office systems)
- HVAC-04 Chillers and Cooling (where most GHG compounds will be found)

Applicability	
Office Scale & Situation:	
	All Organisations
	Larger Offices
X	Operational Control
X	Full Ownership
Climate Zones:	
Applicable to all climate zones	

Capital Cost (US$)	
	No cost
	$0 - 10k
X	$10k - 100k
	$100k - 500k
	>$500k
Payback	
	Instant
	<6 months
	6 - 12 months
	12 - 24 months
X	>24 months
GHG Reductions	
	Enabling Measure
X	<1%
	1 - 5%
	5 - 10%
	>10%

Annex B: Glossary

A

Air Balancing: The process of measuring and adjusting air flow to meet the needs of the occupants.

Air-Cooled System: In an air-cooled system, the condensing coil is exposed directly to the outside atmosphere, requiring refrigerant lines to be run to the office's roof or exterior.

Air Economiser: An outside air economiser is a system that cools an office/building using air from outside the building, and is most effective when the outside air is cooler than the air inside (see also 'Free Cooling').

Ambient Temperature: For the purposes of this Guide, refers to the outside air temperature.

ASHRAE: ASHRAE (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers) is an international organisation that establishes standards for the uniform testing and rating of heating, ventilation, air conditioning and refrigeration equipment.

B

Ballast: An electrical device for starting and regulating fluorescent and discharge lamps.

Baseline Performance: The current existing energy and carbon performance of the office before any improvements and upgrades have been made.

Benchmarking: Comparison of an office's performance with other known performance metrics or data.

Building Management System (BMS): A Building Management System (BMS) is a central computerised system for managing and operating systems within a building.

Building Load Profile: A measure of the time distribution of a building's energy requirements including, heating, cooling and electrical loads.

C

Carbon Dioxide: A chemical compound that is emitted both naturally through the carbon cycle and through human activities such as the burning of fossil fuels. See also 'Greenhouse Gas Emissions'.

Chlorofluorocarbons (CFCs): CFCs are organic compounds that contains carbon, chlorine, and fluorine. CFCs, along with other chlorine- and bromine-containing compounds, have been implicated in the accelerated depletion of ozone in the Earth's stratosphere. Their desirable safety characteristics, along with their stable thermodynamic properties, make them ideal for many applications such as coolants for refrigeration systems. See also 'Hydrochlorofluorocarbons'.

Climate Friendly: For the purposes of this Guide, climate friendly relates to offices that will generate lower GHG emissions during their operation than would be standard practice.

Climatic zone: Geographical zones divided according to prevailing temperature, precipitation and latitude.

Co-generation: Co-generation (sometimes also known as combined heat and power, CHP) is the use of a heat engine/generator to simultaneously generate both electricity and useful heat.

Combustion Efficiency: A measure of useful heat extracted from a fuel source by an operating heating appliance. For example, a furnace with a combustion efficiency of 60 percent converts 60 percent of the fuels energy content into useful heat.

Conduction: A mode of heat transfer in which heat energy is transferred within an object or between objects in contact. Conduction is one of the three forms of heat transfer, which also include ‘Convection’ and ‘Radiation’.

Constant Air Volume (CAV): CAV is a type of HVAC system where the supply air flow rate is constant, but the supply air temperature is varied to meet the thermal requirements of a space.

Convection: A mode of heat transfer in which heat energy is transferred from an object to moving fluid such as air, water, or refrigerant. Convection is one of the three forms of heat transfer, which also include ‘Conduction’ and ‘Radiation’.

Control Damper: See ‘Damper’.

Cooling Degree Days: Cooling degree days (CDD) is a climatological metric used to express the magnitude of the cooling load in a given location. The metric is often expressed in terms of a base temperature such as CDD Base 65 ^{o}F). The greater the number cooling degree day measurement, the more the air conditioner is likely to be running.

Cooling Tower: A heat rejection method that transfers heat energy from an office to the outside atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid or rely solely on air to cool the working fluid.

D

Damper: A movable plate for regulating the air intake into the air conditioning system and office. Can be located to regulate outdoor air (OA), and return air (RA).

Daylighting: The practice of placing windows, or other transparent media, and reflective surfaces so that, during the day, natural light provides effective internal illumination.

Dehumidification: The process of removing moisture from air in order to improve the thermal comfort of an office space.

Diversity Factor: The diversity factor is the ratio of the sum of the individual maximum demands to the total maximum demand, as applied to mechanical and electrical systems.

E

Economiser: See ‘Air Economiser’ and ‘Water Economiser’.

Emissions: Releases of gases to the atmosphere (e.g., the release of carbon dioxide during fuel combustion). Emissions can be either intended or unintended releases.

Emissivity: The emissivity of a material is the relative power of its surface to emit heat by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature. In general, the duller and blacker a material is, the closer its emissivity is to 1, whereas the more reflective a material is, the lower its emissivity.

ESCO: An energy service company (ESCO) is a professional business providing a broad range of energy solutions. The ESCO typically designs, installs and maintains a given energy solution to ensure energy savings during the payback period, where these savings are often guaranteed and underwritten.

F

Free Cooling: A practice where the outside atmosphere is used to directly cool an office. There are two common types of free cooling, namely airside free cooling and waterside free cooling. See 'Air Economiser' and 'Water Economiser'.

Flue Damper: See 'Damper'.

G

Glare: Any excessively bright source of light (often sunlight) within the visual field that creates discomfort or loss in visibility.

Global Warming Potential (GWP): GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by definition 1). A GWP is calculated over a specific time interval.

Greenhouse Gas (GHG): Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

Green Power: Green power refers to renewable energy that is bought by your energy provider on your behalf. Renewable energy is generated from sources like mini hydro, wind power and biomass which produce no net greenhouse gas emissions.

H

Halons: Substances that are used in fire suppression and fire extinguishers in offices and deplete the stratospheric ozone layer (see 'Ozone Depleting Potential').

Heat Exchanger: A device built for efficient heat transfer from one medium to another, whether the media are separated by a solid wall so that they never mix, or the media are in direct contact. There are variety of types, including plate, air-cooled, tube and shell exchangers.

Heating Degree Days: Heating degree days (HDD) is a climatological metric used to express the magnitude of the heating load in a given location. The metric is expressed in terms of a base temperature such as HDD Base 65 F.

Heat Island Effect: The heat island effect is where an urban area is significantly warmer than its surrounding rural areas. The main cause of the urban heat island is modification of the land surface by urban development which uses materials which effectively retain heat.

Humidity: Humidity is the amount of water vapour in the air. Relative humidity is defined as the ratio of the partial pressure of water vapour in a parcel of air to the saturated vapour pressure of water vapour at a prescribed temperature. High humidity makes people feel hotter because it reduces the effectiveness of sweating to cool the body by reducing the evaporation of perspiration from the skin.

HVAC: An abbreviation for Heating, Ventilation and Air Conditioning. Sometimes an 'R' is shown at the end to represent refrigeration.

Hydrochlorofluorocarbons (HCFCs): Refrigerants that deplete the stratospheric ozone layer (see 'Ozone Depleting Potential') and are used in office equipment.

Hydrofluorocarbons (HFCs): Refrigerants that do not deplete the stratospheric ozone layer (see 'Ozone Depleting Potential'), but some do have a high global warming potential.

I

Indoor Air Quality (IAQ): IAQ refers to the nature of air within an office that affects the health and well-being of the occupants.

Intergovernmental Panel on Climate Change (IPCC): The IPCC is a scientific intergovernmental body tasked with evaluating the risk of climate change caused by human activity. The panel was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

L

Light Emitting Diodes (LEDs): An semiconductor electronic light source.

Lux: Lux is the SI unit of illuminance and luminous emittance.

N

Natural Ventilation: The process of supplying and removing air by natural means in office spaces by using openings such as windows, vents and doors.

O

Ozone Depleting Potential (ODP): ODP is a relative value that indicates the potential of a substance to destroy ozone gas as compared with the potential of chlorofluorocarbon-11 (CFC-11) which is assigned a reference value of 1.

Ozone Layer: See 'Stratospheric Ozone Layer'.

P

Plug Loads: Intensity of energy consumption through appliances connected to the electrical system via interior plug sockets.

R

Radiation: A mode of heat transfer in which heat energy is transferred via electromagnetic waves. An item warmed by sunlight is an example of radiant heating. Radiation is one of the three forms of heat transfer, which also include Convection and Conduction.

Refrigerant: The working fluid used in the refrigeration cycle. Modern systems primarily use fluorinated hydrocarbons that are nonflammable, non-corrosive, nontoxic, and non-explosive. Environmental concerns of ozone depletion means refrigerants are under significant scrutiny. See 'Hydrochlorofluorocarbons' and 'Hydrofluorocarbons'.

Retro-commissioning: A systematic process applied to existing buildings for identifying and implementing operational and maintenance improvements and for ensuring their continued performance over time.

R-Value: The R-value is a measure of thermal resistance used in the building and construction industry. Under uniform conditions, it is the ratio of the temperature difference across an insulator and the heat flux (heat flow per unit area) through it. The bigger the number, the better the building insulation's effectiveness. R-value is the reciprocal of U-value.

S

Set Point: User-set or automatic thresholds for heating, cooling, humidification, and dehumidification usually measured in the return air stream of the air conditioner system.

Solar Reflective Index: A measure of a material surface's ability to reflect sunlight, which operates on a scale of 0 to 1, where black paint has a reflectance of 0 and white paint a value of 1. Solar reflectance is also known as albedo.

Stratospheric Ozone Layer: Ozone is a gas that occurs both in the Earth's upper atmosphere and at ground level. The stratospheric ozone layer extends upward from about 6 to 30 miles and protects life on Earth from the sun's harmful ultraviolet rays. This natural shield has been gradually depleted by man-made chemicals like chlorofluorocarbons (CFCs). A depleted ozone shield allows more UV radiation to reach the ground, leading to health and environmental problems.

Supply Air Temperature: Mechanism by which supply air temperature from a ventilation system is reset to match the internal ambient temperature of the target zone.

T

Thermal Comfort: A condition of mind experienced by office occupants expressing satisfaction with the surrounding thermal environment.

T5, T8 and T12: Refers to types of fluorescent lamps. The "T" in lamp nomenclature represents the shape of the lamp-tubular. The number following the "T" usually represents the diameter of the lamp in eighths of an inch. T5 lamps have a diameter of 5/8", T8 lamps are one inch in diameter, and T12 lamps are 1½" in diameter.

Tri-generation: Tri-generation produces heat and power as well as chilled water for air conditioning or for process use with the addition of absorption chillers that take the waste heat from co-generation to make chilled water for cooling a building.

U

U-value: The U-value measures how well a product prevents heat from escaping. It is a measure of the rate of non solar heat loss or gain through a material or assembly. The rate of heat is indicated in the terms of the U-value of a window assembly which includes the effect of the frame, glass, seals and any spacers. The lower the U-value, the greater a window's resistance to heat flow and the better its insulating value.

V

Variable Air Volume (VAV): System that relies on the throttling of air volume to control temperature, and thus save energy during partial load conditions.

W

Water-Cooled System: A type of cooling system that uses water instead of air as a condensing medium. Condensation takes place in a refrigerant/water heat exchanger and the water flows in a continuous loop to an outdoor cooling tower where heat is rejected to the outside atmosphere.

Annex C: Acronyms

ADB	Asian Development Bank
AFDB	African Development Bank
AHU	Air handling unit
CEB	Chief Executive Board
ECLAC	Economic Commission for Latin America and the Caribbean
ESCO	Energy service company
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air-Conditioning
ICTY	International Criminal Tribunal for the former Yugoslavia
IMF	International Monetary Fund
INFM	Inter-Agency Network of Facilities Managers
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt Hour
LED	Light-emitting diode
MMBTU	One thousand thousand British Thermal Units (also expressed as MBTU)
O&M	Operation and maintenance
SUN	Sustainable United Nations
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNEP SBCI	UNEP's Sustainable Buildings and Climate Initiative
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization

UNESCWA	United Nations Economic and Social Commission for Western Asia
UNICEF	United Nations Children's Fund
UNHCR	United Nations High Commissioner for Refugees
VIC	Vienna International Center
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information,
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UNEP

The first assessment of the United Nations (UN) system's carbon footprint was published in December 2009. A breakdown of greenhouse gas (GHG) emissions revealed that about 40 per cent of emissions come from operating the buildings and offices, which the UN maintains in more than 530 locations worldwide. The majority of these are leased or rented and are often managed and maintained by the UN.

However, as ownership belongs to other parties, typically the opportunities for major renovations and investments are limited. Acknowledging that in most instances the office space is leased, this Climate Friendly Buildings and Offices: A Practical Guide provides practical advice on what can be done to reduce GHG emissions under these circumstances, and how these opportunities can be identified and assessed.

The Guide focuses on GHG emission reduction opportunities from existing offices, and therefore on energy efficiency and conservation.

DTI/1278/PA