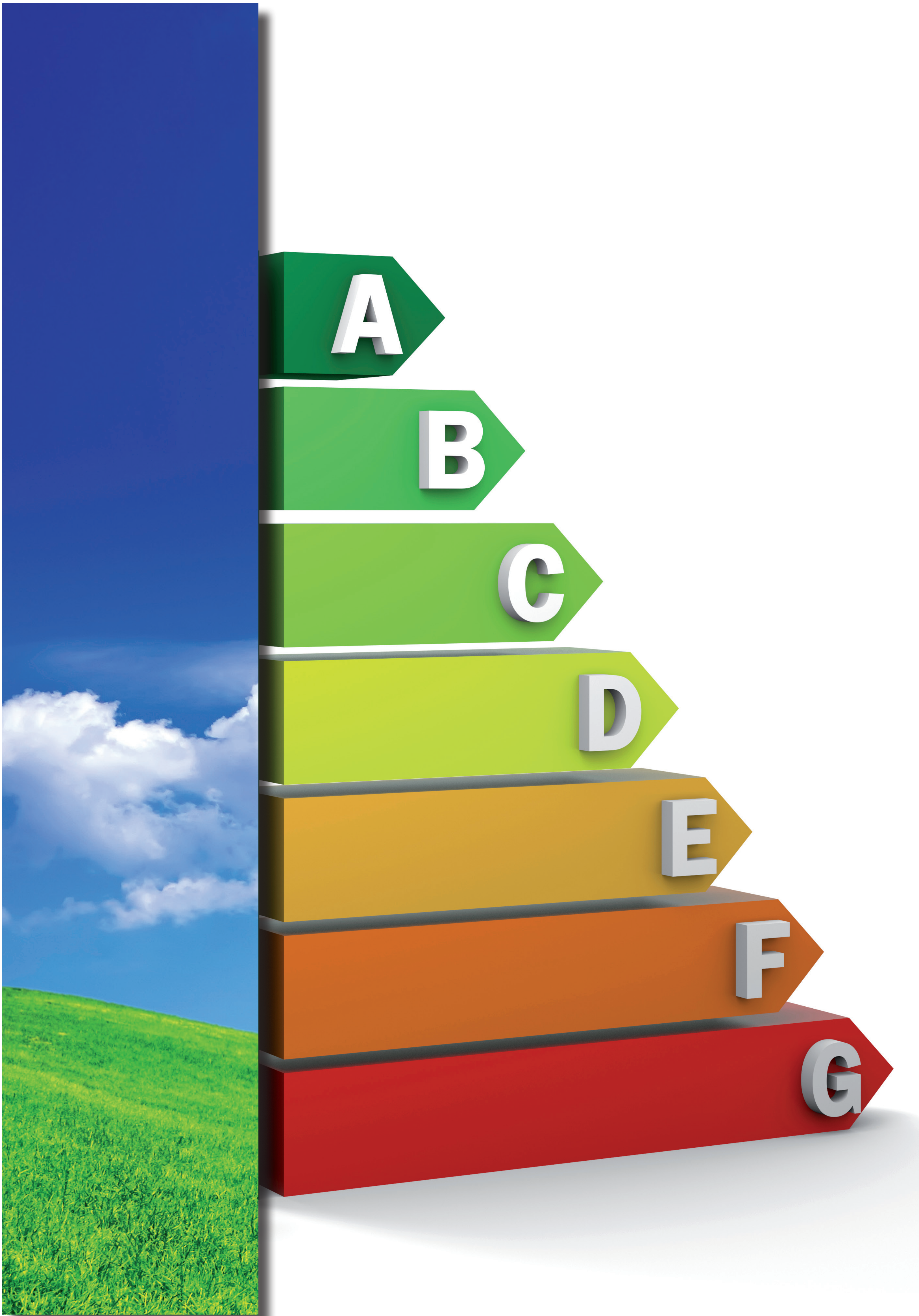
Energy Efficiency Handbook

Environmental Housekeeping Handbook for Office Buildings in the Arab Countries

المنتدى العربي للبيئة والتنمية
ARAB FORUM FOR
ENVIRONMENT AND DEVELOPMENT
AFED

A PRODUCT OF AFED'S ARAB GREEN ECONOMY INITIATIVE (AGEI)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Arab Forum for Environment and Development (AFED) is a not-for-profit organization, which brings the business community together with experts, civil society and media, to promote prudent environmental policies and programs across the Arab region.

One of the main goals of AFED is propagating environmental awareness by means of supporting the role of environmental education and information and of non-governmental organizations active in environmental protection.

The main product of AFED is a periodic expert report on the state of the Arab environment, tracking developments and proposing policy measures. Other initiatives include a regional corporate environmental responsibility (CER) program, capacity building for Arab civil society organizations, public awareness, and environmental education.

ENERGY EFFICIENCY HANDBOOK

This handbook is intended for use as a housekeeping guide for energy efficiency best practices in office buildings across the Arab region.

Prepared and adapted to the Arab region by AFED, based mainly on Climate Corps Handbook, with permission from Environmental Defense Fund (EDF).

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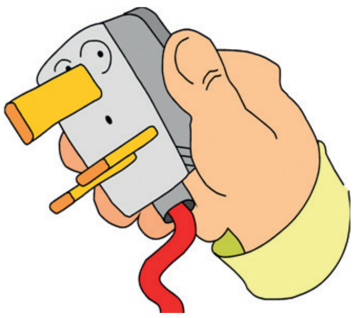
Foreword

Arab economies are not energy efficient. Recent data about annual CO_2 emissions per capita and per unit of gross domestic product (GDP) for some Arab countries bear that out. The demand for energy is rising across all Arab countries fueled by economic and population growth, as well as by increased industrialization and urbanization and changing life styles. For oil-importing countries, the high price of oil is having a significant impact on their balance-of-payments. For oil-producing countries, rapidly rising electricity demand has caused power black-outs in recent years.

As a result, governments are allocating tens of billions of dollars over the next decade for the construction of additional power plants and for upgrading the grid. Moreover, many Arab countries are interested in nuclear power to complement the primary sources of electricity generation, oil and natural gas. However, these significant investments yield little economic returns because of low end-use efficiency and high subsidies. It will not be economically sustainable to subsidize energy use for millions of institutional and household end-users. Energy planners in Arab countries face daunting challenges.



Energy policy in Arab countries should not be concerned solely with the expansion of energy supply to meet the increased demand for electricity. The management of the supply side must be coupled with demand-side management. Energy policy makers should treat energy efficiency as a strategic policy objective, worthy of strong commitment. In fact, managing the demand for energy through energy efficiency should become a priority *now* before significant investments are locked in new power plant facilities. Capitalizing on energy efficiency would in effect reduce the demand for power and hence the immediate need to build new power generation plants. Studies have indicated that scalable energy efficiency opportunities can reduce energy consumption by 30%.

Because it is subsidized, energy consumption may not be of concern to end-users in many Arab countries. In fact, the monthly electricity bill for most organizations makes up a negligible portion of total monthly operating costs. However, there is more to this story. While thousands of end-users may not be burdened by electricity costs, it is the national economy that becomes saddled with significant subsidy costs and more critically with the high costs associated with building new power plants. Subsidies lead to overconsumption, impose a burden on public finances, misallocate resources, and constrain the ability of regulatory agencies to rein in demand. The indirect effects include lower economic productivity, increased air pollution, and higher rates of greenhouse gas emissions. These dynamics create a reinforcing cycle. High subsidies promote overconsumption, which drives the demand up, thus prompting more power plant construction, and leading to even higher subsidies.
One of the barriers to improving energy efficiency is the lack of awareness

of practical, cost-effective methods for reducing energy consumption. This handbook helps to fill a large gap on energy efficiency strategies in commercial buildings in Arab countries. The handbook was developed to assist organizations identify and prioritize cost-effective energy efficiency opportunities in commercial buildings.

Energy supply and end use systems, such as buildings, require large capital investments and have long turn-over times: 30-40 years for energy systems and 100 years for buildings. Because investments have been sunk into these facilities, the only practical means to reduce energy use lie in systemically capturing energy efficiency opportunities. Minute reductions in lighting energy consumption in buildings will translate into considerable savings when aggregated. When other energy uses - HVAC, equipment, and data centers - in buildings are targeted, and when thousands of commercial buildings are included, the individual minute reductions will aggregate to significant energy savings in kilowatt-hours and in considerable cost reductions. The consumer will benefit, and so will the whole economy and the environment.

The Arab Forum for Environment and Development (AFED) hopes that the Energy Efficiency Handbook will inform stakeholders and stimulate action for enabling a cost-effective energy efficiency strategy at the national and regional levels.

A preview copy of this handbook was released in November 2011, under the title Environmental Housekeeping Handbook, in cooperation with Philips Middle East and Africa, a regional corporate member of AFED. This was a part of AFED's Arab Green Economy Initiative. The Handbook was put into practice among AFED members for the past ten months, during which revisions were made based on the feedback received. As a result, this revised edition has been produced, incorporating various changes, updates and additions. It is available in English and Arabic versions, both hardcopy and online.

This endeavor was made possible with the cooperation of three partners who contributed to the contents and the production costs, namely Royal Philips Electronics of the Netherlands, Musanadah of Khalid Ali Alturki & Sons Company in Saudi Arabia, and MED-ENEC, the European Union-funded program which promotes energy efficiency and renewable energy use in the construction sector in southern and eastern Mediterranean countries.

November 2012

Najib Saab
Secretary General
Arab Forum for Environment and Development (AFED)

Energy efficiency programs yield the following benefits:

Economic benefits:

1. Lowering energy bills for end-use consumers over the lifetime of the building's occupancy.
2. Reducing the size of government energy subsidies and improving countries' balance-of-payments.
3. Lowering peak electric demand levels, which reduces strain on the electric grid and the need to build costly new power plants, yielding billions of dollars in cost savings.
4. The reduction in energy consumption will also put downward pressure on overall energy prices, thus generating additional energy cost savings for all consumers and for the government.
5. Improving the long-term reliability and stability of the electric grid and other sub-systems of the energy infrastructure system.
6. Enhancing economic resource productivity and economic competitiveness.
7. Investments in energy efficiency will create value-adding economic activities and new jobs.

Environmental benefits:

8. Improved efficiency standards are critical for avoiding significant emissions of greenhouse gases (GHG) and for meeting national climate change goals (if any) at the lowest possible overall cost.
9. Reduced water consumption (used in generating steam) in power plants.
10. Energy efficiency contributes to reduced emissions and formation of toxic air pollutants—NO_x, SO_x, ground-level ozone (smog), particulate matter, volatile organic compounds, and others.

ABBREVIATIONS

ACEEE	American Council for an Energy Efficient Economy
AFED	Arab Forum for Environment and Development
AC	Alternating current
AREE	Aqaba Residence Energy Efficiency
ARI	Air-Conditioning & Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building automation system
BIEC	Best-in-efficiency class
BMS	Building management system
CADE	Corporate average data efficiency
CFL	Compact florescent lamp
CFO	Chief financial officer
CIBSE	Chartered Institution of Building Services Engineers
CLASP	Collaborative Labeling and Appliance Standards Program
COP	Coefficient of performance
CPU	Central processing unit
DC	Direct current
DCiE	Data center infrastructure efficiency
EDF	Environmental Defense Fund
EER	Energy efficiency ratio
EF	Energy factor
EI	Energy intensity
EIS	Energy information system
E&M	Electro-mechanical
EMS	Energy management system
EPO	Environmental performance officer
GDP	Gross domestic product
GHG	Greenhouse gas
GPM	Gallons per minute
HID	High intensity discharge
HP	Hewlett Packard
HSPF	Heating season performance factor
HVAC	Heating, ventilation, and air-conditioning
IPLV	Integrated part-load value
IRR	Internal rate of return
IT	Information technology
kWh	Kilowatt-hours
LCD	Liquid crystal display
LCEC	Lebanese Center for Energy Conservation
LED	Light-emitting diode
O&M	Operations & maintenance
MENA	Middle East and North Africa
NPV	Net present value
PC	Personal computer
ppm	Pages per minute
PUE	Power utilization effectiveness
PV	Photovoltaic
RoI	Return on investment
SEER	Seasonal energy efficiency ratio
SWH	Solar water heater
TAB	Testing, adjusting, and balancing
TOE	Ton of oil equivalent
UPS	Uninterruptible power supply
US$	United States Dollar
USEPA	United States Environmental Protection Agency
VAV	Variable air volume
VSD	Variable-speed drive

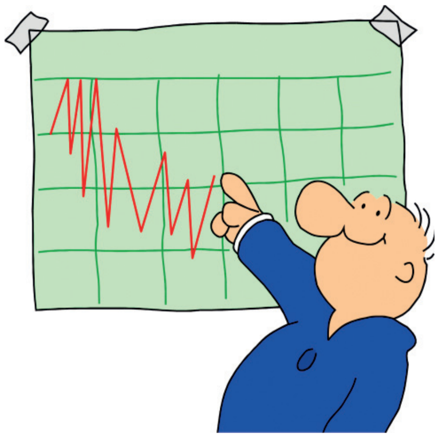
CHAPTER 1 Introduction

ENERGY EFFICIENCY HANDBOOK OBJECTIVE

The Energy Efficiency Handbook assists occupants of commercial buildings in Arab countries capture unrealized financial and environmental gains. The handbook presents methodologies for systemically identifying and prioritizing cost-effective investments that result in energy savings for building owners or leaseholders.

ENERGY EFFICIENCY MATTERS

Increasingly, companies and government agencies in Arab countries see improving energy efficiency as a critical tactic for cutting costs and greenhouse gas (GHG) emissions. The costs of heating and cooling in inefficiently designed and constructed buildings are putting an increasing financial burden on occupants, particularly in those countries—Jordan and Morocco—where fuel and electricity subsidies are gradually being removed. Even in high-income Arab countries with significant energy subsidies for end-users, supply is unable to meet soaring demand for electricity. End-use energy efficiency in buildings offers a cost effective strategy to reduce electricity consumption compared with, for instance, expansion of supply capacity. In fact, end-use energy efficiency improvements are the surest, cleanest, and least expensive option to meet increased demand.

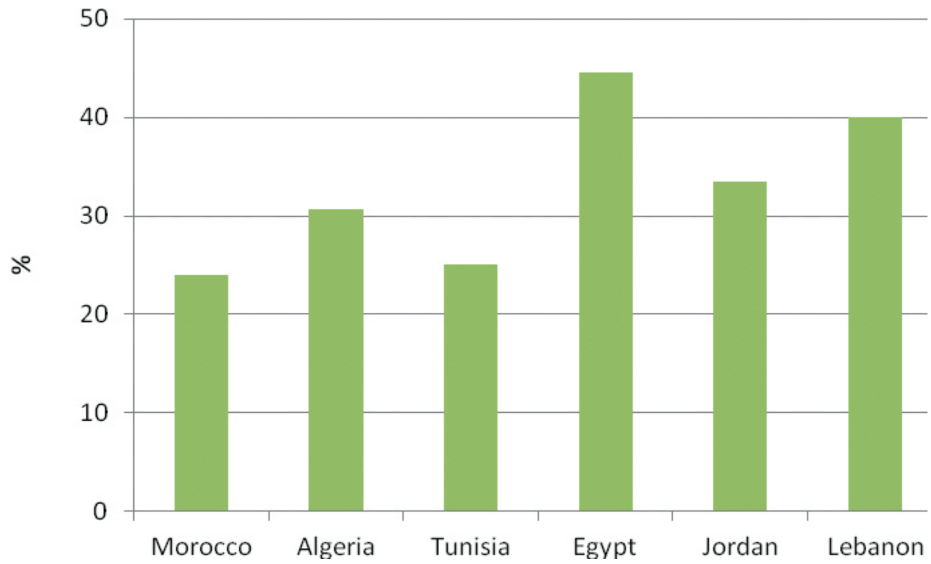


In Arab countries, buildings account for an average of 35% of all final energy consumption, and contribute 35-45% of all CO_2 emissions. Most of these impacts occur in the occupancy phase of the building lifetime. Figure 1.1 indicates the share of the buildings sector of the final energy consumption in selected Arab countries. Moreover, the building sector is one of the fastest growing sectors in the Arab region. It is projected that a total of $4.3 trillion will be spent on construction in the Middle East and North Africa (MENA) region over the next decade. The bulk of this construction will be directed towards new residential, commercial, and public buildings such as hospitals and schools. Therefore, a common challenge will be the sector's significant use of resources and emissions of CO_2. These projections give proof that prudently managing energy consumption in buildings matters significantly.

Global studies have demonstrated that most commercial buildings could cut energy use by 30% or more through investments in improved efficiency. Despite the opportunities, few companies in Arab countries have fully invested in cost-effective energy efficiency improvements. A number of barriers prevent these companies from identifying or approving smart efficiency investments. One of the most often cited barriers is the lack of knowledge by companies and end-users about the opportunities that exist and how to take advantage of them.

This handbook offers a roadmap that can be used by office or facilities managers in Arab countries to identify, assess, and prioritize energy investment opportunities that will lower their energy use and hence reduce their carbon footprint. The handbook's primary focus is on the largest consumers of electricity in an office building including heating, ventilation, and air conditioning (HVAC), lighting, water heating, and office equipment such as computers, copiers, and printers. The handbook takes a generalized approach to improving energy efficiency in office buildings, and therefore, users may have to tailor some contents to the specific conditions of their location. In addition to addressing efficiency in electric power use, the handbook contains a chapter to address reducing fuel use by company-owned or company-leased vehicles.

FIGURE 1.1: SHARE OF BUILDING SECTOR IN THE FINAL ENERGY CONSUMPTION IN SELECTED ARAB COUNTRIES



Source: MED-ENEC, 2006

Office buildings are those used for general office space, professional offices, or administrative offices. This category includes: administrative or professional office, company's head office, government office, mixed-use office, bank or other financial institution, medical office without diagnostic equipment, sales office, contractor's office, non-profit or social services, research and development, city hall, or city center.

An office building is one category among others that make up commercial buildings. While this handbook targets *office* buildings, many of the energy efficiency investments described apply just as well to other types of commercial or institutional buildings such as retail buildings, shopping centers, hospitals, hotels, schools, and universities. Again, office and facilities managers would be prudent to tailor the content to the specific requirements, functions, and conditions of the building category in question.

It must be acknowledged that the work presented in this document relies primarily on the 2009 Environmental Defense Fund (EDF) report "Climate Corps Handbook: Energy Efficiency Investment Opportunities in Office Buildings."

CHAPTER 2 How to Use this Handbook

This handbook is a reference manual for identifying, analyzing, and prioritizing energy efficiency investments in commercial office buildings and data centers. The handbook contains a set of chapters focusing on areas of a typical building's energy use—lighting; heating, ventilation, and air-conditioning (HVAC); office equipment; and water heating—and associated energy saving opportunities. Each chapter provides an overview of steps that can be taken to reduce energy use, from policy changes to efficient use adjustments and equipment replacement. Additional chapters detail the energy savings potential of installing or upgrading an energy management system (EMS) and the efficiency opportunities that exist in data center facilities. The reduction of fuel consumption by vehicles is also addressed.

Chapters are also devoted to additional concepts that will be useful to office and facilities managers: traditional barriers to energy efficiency investment, how to interpret office energy bills, basic energy efficiency finance, and additional non-financial considerations. Additional background information is included in the appendices.

Each chapter contains a set of goals, topical overview and 'Information Gathering Guide', which outlines information that a facilities or office manager should collect internally or from external sources. The chapters contain rough estimates of costs, typical energy savings, and expected returns on investment for a number of the suggested efficiency upgrades. These estimates will vary by country, and therefore, handbook users are advised to consult contractors and vendors for more accurate cost figures. References are listed for a reader who may want to delve deeper into a particular practice or technology.

Another useful approach when presenting companies with a business case for investment in energy efficiency is to cite relevant case studies from organizations that have made successful investments. In addition to the short case studies in a number of individual chapters, more detailed case studies are included in the appendices.

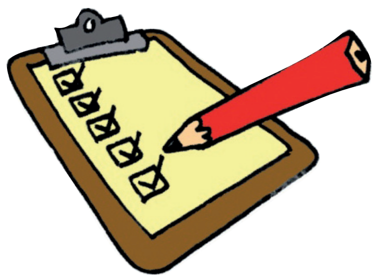
Although the challenge of greatly improving energy efficiency in buildings may appear daunting at first, a good approach is to start with relatively low-cost, simple projects. As such, this handbook focuses on relatively simple and low-cost efficient technology options. The energy reduction tactics in each chapter are presented in order from simplest and lowest cost (e.g., policy and process changes) to more complex and cost-intensive (e.g., equipment replacement).

CHAPTER 3 Steps to Identify and Prioritize Possible Efficiency Measures

INTRODUCTION

Opportunities for incorporating greater energy efficiency into commercial buildings can occur in many stages of the building's life cycle, including:

- New building design and engineering.
- Acquisition and leasing.
- Refurbishment and upgrade projects.
- Asset valuation.
- Operations and facilities management.



This handbook focuses primarily on the final stage, operations and facilities management, and suggests measures that are suitable for retrofitting or replacing existing building technologies. Stakeholders involved in earlier stages of a building's life cycle may still find practical information in the handbook of use. The following outlines the basic steps for identifying and prioritizing energy efficiency opportunities.

1. Estimate baseline energy use intensity

Calculation of baseline energy intensity (EI) can be performed by dividing the annual purchased electricity or amount of fuel by gross area of the office space. In order to perform this analysis, you need to obtain documentation of purchased energy (e.g., monthly electricity and natural gas bills) from the previous fiscal year. It is advisable to take regular monthly meter readings to reconcile them with the electricity bills. Baseline estimates of EI can be compared to benchmarked energy use intensity figures to provide a rough estimate of potential gains to be attained through energy efficiency measures. For more information on estimating baseline energy use and benchmarking, see Chapter 5: Interpreting energy bills and benchmarking energy use.

If benchmarks cannot be obtained, it is recommended to set a target for reducing energy intensity as a percentage of the baseline EI over a given period of time. For example, a facilities manager may target a reduction in current baseline EI by 20% to be reached over a three-year period.

2. Commission an energy audit

If initial energy intensity benchmarking calculations reveal that an office space is not maximally efficient, the next step is to commission a professional energy audit. The purpose of an energy audit (or survey) is to evaluate an existing building to determine how energy is being used. The utility history is first obtained and reviewed to assess the energy costs and usage for the facility. The various building energy systems are checked and inspected to determine if they are operating efficiently. Inspections typically cover lighting systems and all aspects of HVAC equipment and systems, including plant units and air and water distribution systems. The building envelope is inspected including doors, windows, and roofs, and the wall construction/insulation is assessed.

The findings of an energy audit can be used to identify and quantify opportunities for reducing energy consumption while improving comfort for office occupants. Efficiency measures will vary from low to no-cost improvements in system settings and use to full system replacements. Energy audits often reveal obvious inefficiencies such as faulty HVAC controls. Correcting these problems should be a first priority, and is likely to yield quick returns.

3. Consider interactions between systems

It is important that evaluation of possible efficiency upgrades be conducted with a holistic focus—a change to one system may alter the conditions of other systems throughout the office space. For example, efficiency upgrades to a lighting system will result in reduced releases of heat and will lower the cooling load of the air-conditioning system. Reductions in cooling load because of improved efficiency of lighting or office equipment can sometimes be significant enough to reduce the cooling load of an HVAC system. The energy engineer(s) should be able to provide good estimates of the probable collateral effects of a given efficiency upgrade, and these should be factored into financial analysis and prioritization.

4. Perform financial analysis of possible efficiency investments

For each potential project, one should forecast the initial incremental investment plus the expected annual savings and costs. Reduction in energy usage will likely be the main financial driver, but changes in labor and replacement costs may also be significant. Financial analysis tools that are used may include net present value (NPV) determination, return on investment (RoI) calculations, and/or the expected payback period. The finance department of your company can provide additional guidance.

5. Prioritize options for investment

Investments should be ranked based on the NPV analysis as well as the size of the initial investment and feasibility. Small and easy NPV positive investments should be implemented immediately. Larger investments will often create greater energy savings but need to be budgeted and managed with greater resources.

6. Evaluate financing options

Investments can be paid for in cash, financed with a loan, leased, or financed through a performance contract (see Chapter 13: Energy efficiency finance). The best option for a given company will depend on the company's cash position, budget cycle, availability of incentives, and purchasing policy. It is a good idea to work with the chief financial officer (CFO) and finance managers to make recommendations based on all of these elements.

7. Post-implementation follow-up

Once the recommended efficiency upgrades have been completed, it will be important to follow up with post-project energy monitoring to quantify and document the effects of the efficiency upgrade.

CHAPTER 4 Barriers to Energy Efficiency

There are many fundamental barriers that impede energy efficiency investments and/or measures in office buildings in Arab countries. The most important of these are financial barriers followed by structural and organizational barriers.

FINANCIAL BARRIERS

- Subsidized electricity in Arab countries creates a disincentive for investing in energy efficiency. According to Khatib (2005), in Arab countries "electricity tariffs of 2-3 cents/kWh are not uncommon." These tariffs are well below the global average commercial rates of 6-9 cents/kWh. Government-subsidized electricity distorts market prices and leads to inefficient allocation of resources and over-consumption and weakens the economic rationale for investing in managing demand by the end-user.

- Efficiency investments may require a significant up-front capital cost outlay, followed by years of stable and predictable savings. Lack of available cash or financing can impede these investments. Budget cycles may also dictate the timing of any investments.

- Many companies impose overly stringent hurdle rates. For example, many companies will not make investments in efficiency measures if the payback period exceeds two years.

- Public or private power utilities in Arab countries do not have the capacity to offer financial incentive that would permit the end-users to invest in energy efficiency upgrades.

STRUCTURAL BARRIERS

- Split incentives that occur when benefits from an investment made by tenants accrue to the landlord or vice versa. For example, if the tenants' electricity is included in the rent, they have little incentive to reduce their electricity use. If the tenants are sub-metered or pay for electricity directly, however, the incentive to make changes is stronger. However, the financial incentives in Arab countries are lacking in general, as mentioned earlier.

- Short or imminent lease schedules also impose financial constraints. Few tenants would invest in projects with a five-year payback if they may depart within three years.

ORGANIZATIONAL BARRIERS

- Scarce resources in the organization means there is limited time to evaluate and implement efficiency investments. Other, more immediate tasks are given higher priority.

- The lack of awareness or knowledge about how to reduce energy consumption makes it difficult for facilities managers to conceive and develop an energy efficiency plan. Insufficient knowledge base within the industry and weak capacity within local supply chains may preclude office managers from pursuing efficiency upgrades.

- ‘Language barriers’ between finance and facilities make it difficult for facilities managers to develop and present a solid business case in appropriate financial terms. In some companies, capital outlays are managed separately from operating expenses, making it difficult to justify a capital expense that reduces operating expenses.

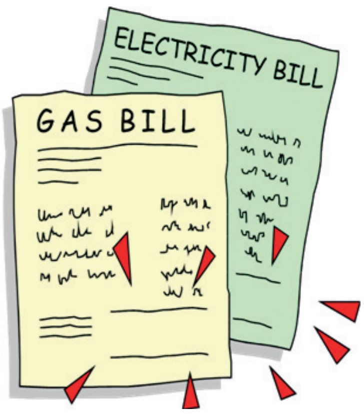
- Coordination challenges across finance, human resources, and facilities make it time consuming to implement efficiency improvements such as HVAC or lighting upgrades while also ensuring that worker comfort and productivity are not affected.

- Limited accountability for green initiatives means that no one department may be responsible for getting initiatives funded and implemented. For example, funding for software to reduce energy consumption in personal computers (PCs) may come out of an IT budget, whereas the energy savings benefit is reflected in the facilities budget.

CHAPTER 5 Interpreting Electricity Bills and Benchmarking Energy Use

OBJECTIVES

- Understand the amount of electricity (and other energy sources such as gas or diesel) used at the host company and current payment and pricing structure.
- Benchmark electricity and gas/diesel usage against similar facilities.



OVERVIEW

Tenants can pay for electricity through one of three ways:

- **Direct meter:** The tenant contracts with, and is billed by the utility directly.
- **Sub-meter:** The tenant pays the landlord based on the meter as well as a negotiated 'handling fee'.
- **Rent inclusion:** The tenant pays a fixed amount per square meter.

Direct meter or sub-meter are the most widely used vehicles for tenants to pay for their electricity in Arab countries, and it is also the most effective in promoting energy efficiency. If a tenant is **directly metered** or **sub-metered**, there will be a financial incentive to improve the energy efficiency of the office space. Any reductions in usage or in **peak demand** will directly reduce the tenant's monthly utility bills. However, if the tenant is paying for energy by **rent inclusion**, there will be little financial incentive to reduce usage until a sub-metering agreement is negotiated.

There are several different ways utilities charge large customers:

- **Energy and demand:** This is the most common pricing scheme. The amount of payment made at the end of each billing period is based on an energy charge and a **demand charge**. The energy charge is based on the total amount of energy used and is measured in kilowatt-hours (**kWh**, a unit of work). The demand charge is based on the maximum load in kilowatts (kW, a unit of power) drawn by the tenant, normally recorded over a 15-minute time interval each month. The demand charge is significant because it sets the amount of generation capacity the utility needs to have to meet customer demand. Building new power plants is expensive and can lead to higher electricity rates for customers. As a result, utilities try to control customer load growth to defer building new generation capacity for as long as possible through demand charges and conservation programs. Therefore, in order to reduce electric bills, companies must either reduce the amount of electricity they use or reduce the maximum amount of electricity they use at any one time.

- **Time of use:** This pricing scheme is also based on energy use and demand; however, there are different rates for peak and **off-peak** demand and different seasons. Under this scheme, electricity drawn during periods of highest demand will be more expensive than electricity drawn during periods of lower relative demand.

- **Real-time pricing:** Prices vary by hour and day, and are linked to the wholesale market price.

BENCHMARKING ENERGY USAGE

The energy intensity of a facility can be expressed with two values: electricity intensity and fuel intensity. To calculate these values for an office building or floor, simply divide total electricity or fuel usage of the space over one year by the total area of the office space.

For example, if building X has 20,000 square meter (m^2) of office space with annual electricity consumption of 1,000,000 kWh and annual natural gas consumption of 7,500 therms, then:

electricity intensity = 1,000,000 kWh/year DIVIDED BY 20,000 m^2 = 50 kWh/m^2-year

fuel intensity = 7,500 therms/year DIVIDED BY 20,000 m^2 = 0.375 therms/m^2-year

TARGET SETTING

There are two methods to set an energy efficiency target:

- **Compare with benchmarks:** To determine how a building performs compared to similar buildings, compare its energy intensity values to known benchmarks for the building type and geographic area. If a given building has energy intensity values that are higher than the benchmarks, there likely will be significant potential for cost effective energy efficiency improvements.

- **Set energy reduction target as a percentage of baseline EI:** If benchmarks are not readily available, a target may be selected as a percentage (e.g., 15% or 25%) of current energy intensity values to be reached over a period of time (e.g., 2 or 3 years).

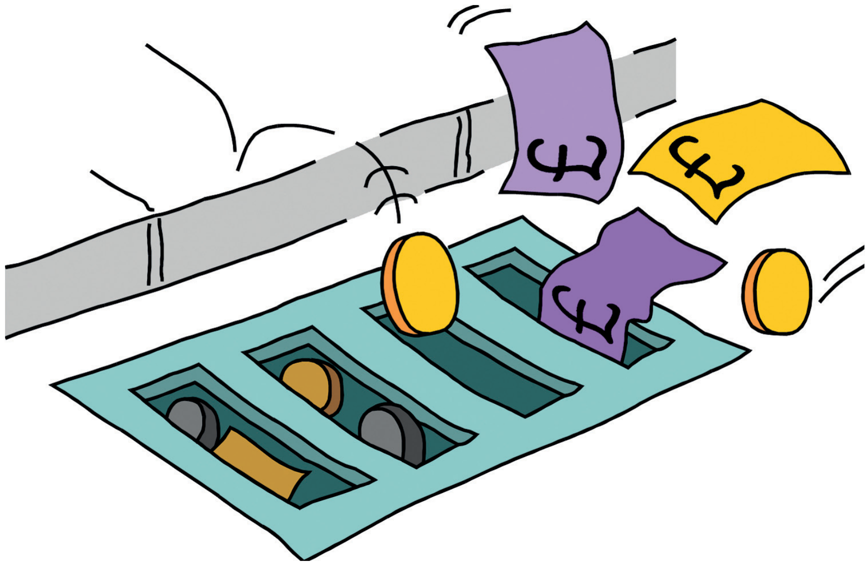
INFORMATION GATHERING GUIDE

The facilities manager or head of operations should have information about electricity usage. Below are commonly asked questions:

- Ask for monthly electricity bills going back at least two years.
- How many meters are in the building? What portion of the facilities do they cover?
- Does the tenant pay the utility directly for energy use or are payments made to the landlord or management company?
- What is the tenant's electricity pricing or rate structure agreement?
- How many employees are located in the space?
- Are there any employee activities that drive significant incremental energy usage (e.g., high intensity computing)?
- What is the area of the office space? What is the area of the office space that uses cooling or heating loads?

Data collection about the number, type, and location of various meters in the building can be facilitated by using the checklist at:

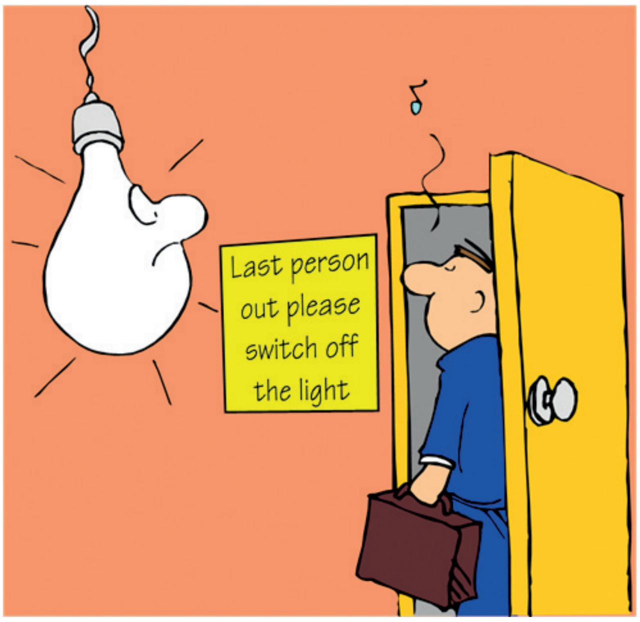
http://www.med-enec.eu/sites/default/files/user_files/downloads/Checklist%20 6energy%20meters.pdf



CHAPTER 6 Lighting

OBJECTIVES

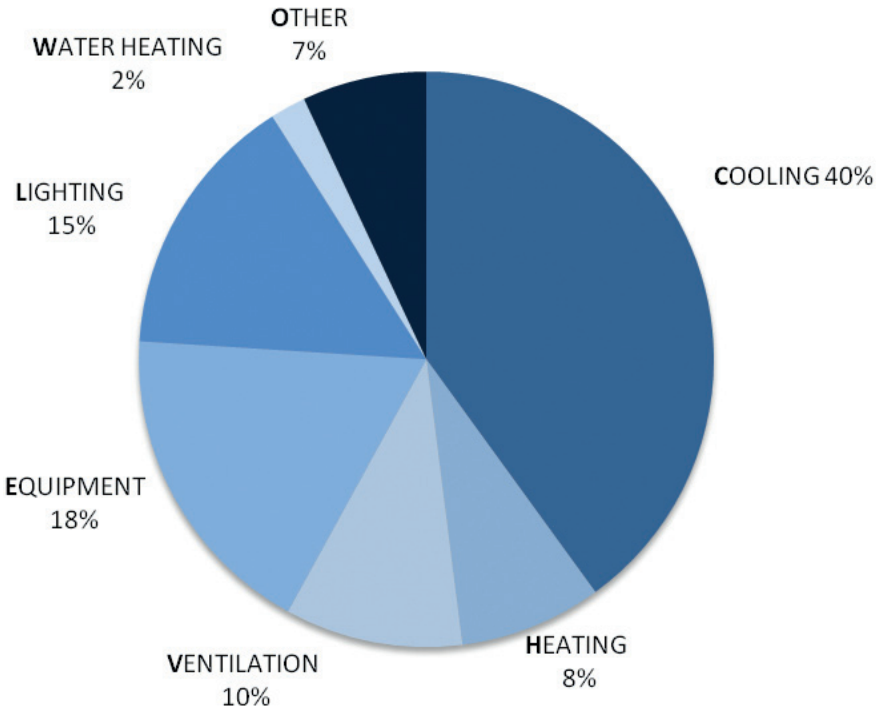
- Achieve proper lighting levels to maximize indoor environmental quality with minimum energy expenditure and without sacrificing comfort or functionality.
- Identify lighting energy efficiency measures.
- Develop estimates of actual energy usage and calculate the estimated savings potential of implementing lighting energy efficiency measures.



OVERVIEW

Lighting accounts for 15-25% of the total energy consumed in a large office building in Arab countries. For illustrative purposes, Figure 6.1 provides a hypothetical energy consumption breakdown in a large office building (>10,000 square meters). Many office buildings operate with highly inefficient lighting systems that are fast becoming outdated. Lights are often kept on in unoccupied workspaces. Artificial lighting is used where daylight can provide more effective illumination at a lower (or no) cost. In addition to having a high-energy demand, inefficient lighting systems release a large portion of drawn electricity as waste heat, adding to an office's cooling load and requiring additional energy expenditure for air-conditioning. As a result, increasing lighting efficiency not only lowers energy costs associated with lighting, but it may also reduce energy costs associated with HVAC.

FIGURE 6.1: HYPOTHETICAL ENERGY CONSUMPTION BREAKDOWN IN A LARGE OFFICE BUILDING IN A GIVEN ARAB COUNTRY



Available lighting technologies are still inherently inefficient. To give an order of magnitude estimate, incandescent lamps convert practically 6% of drawn electricity input into useful light, while the much lauded compact fluorescent lamps (CFL) have an efficiency of about 24%. Light-emitting diodes (LED) fare the best currently with a 27-45% conversion efficiency to visible light. The balance dissipates as waste heat.

Taking into account primary conversion efficiency at the power plant and grid transmission losses, the conversion efficiency from primary energy to useful light is 9% for CFL and a mere 2.4% for incandescent light lamps. In other words, if the power plant consumes 1,000 kg of fuel to generate electricity for lighting, only 90 kg will be turned into useful light if CFLs are used, while only the equivalent of 24 Kg will be transformed into light if incandescent bulbs are used. Every kWh of incandescent bulb operation will result in the emission of around 17 Kg of CO_2, while the same kWh consumed by a CFL will result in 3 Kg of CO_2. Consequently, efficient lighting is key to reducing energy use in office buildings.

The efficiency of an office lighting system can be increased through:

- Education and behavioral changes, such as encouraging office occupants to turn off unnecessary lights.

- Lighting controls that ensure light levels are adjusted to the correct intensity and lamps are illuminated only when and where they are necessary.
- Upgrading lighting systems with higher efficiency technologies.

- In addition, the following principles and guidelines are to be followed in order to reach efficient energy utilization for lighting systems:

- Keep lighting fixtures clean and in perfect working order.
- Enhance the optical characteristics of the space being lit.
- Replace inefficient light bulbs and/or fixtures/accessories with energy efficient ones.
- Use enough light as required by the task.
- Wherever possible, replace artificial light with natural light.

INFORMATION GATHERING GUIDE

It is important to consider a number of questions about the building before you assess the building's lighting efficiency potential, including:

- Does the occupant own or lease the office space?
- If the occupant leases its office space, does the tenant pay the utility bill or is it included in the rent? (See Chapter 5: Interpreting electricity bills and benchmarking energy use)
- Is the landlord interested in pursuing energy efficiency?
- Who in the tenant's organizational structure makes lighting design and purchasing decisions?
- What upgrades have been made to lighting in the last three to five years?
- How often is the office space renovated?
- How much outdoor lighting is required for security?
- Are there any official lighting policies (e.g., lights to be dimmed after 18:00)?
- What is the occupancy schedule for the office?
- How are lights controlled? Which systems are automated and which are manually controlled?
- What are the responsibilities of cleaning staff with regard to lighting?
- What are the responsibilities of security staff with regard to lighting?
- Was an energy audit performed in the last 3 years? If so, what were the findings of the audit? Were the recommended efficiency measures implemented?
- Is a floor plan of the office space available? Are electrical drawings available?

Carry out a walk-through of the office building during workday hours and then again after office hours and note lighting levels. This simple exercise can help you calculate a rough estimate of lighting savings potential. During the walk-through, the following questions should be considered:

- For each room or zone, are the lights on during the day/evening?
- When rooms are (un)occupied, is the lighting adequate? Excessive?
- What is the type and wattage of lamps used in the building?

A lighting engineer can offer more detailed assessment capabilities as well as a broader range of solutions.

TACTICS FOR REDUCING LIGHTING ENERGY USE

Lighting energy efficiency measures are divided mainly into those related to behavioral changes and management policies, those that involve lighting control devices, and those that require upgrades and/or replacement of hardware. The former includes usually no-cost or low-cost interventions while the latter ranges from simple low cost measures to relatively more complex and capital-intensive changes. Lighting systems are fairly complex propositions, and therefore should be handled by competent professionals. Many of the measures listed below require the intervention of an energy audit company, a lighting consultant, and specialized contractors.

SUCCESSFULLY IMPLEMENTED LIGHTING ENERGY EFFICIENCY MEASURES THAT RELY ON STAFF COOPERATION IS A SIGN OF GOOD MANAGEMENT PERFORMANCE.

A) POLICY AND PROCESS CHANGES

A1) Train/educate staff to turn OFF the lights when rooms are not occupied. The simplest efficiency measure a company can make is to institute policies and processes to ensure lights are switched off when the office space is vacant. You will need to determine who among users of the space should have primary responsibility for turning lights on and off at different times of the day and week and make sure that those responsibilities have been communicated. Increased coordination among staff, from office managers and office occupants to cleaning and security crews, can often result in the implementation of this policy. Installing a master switch that can turn off all lights on a floor will make it easier for the last to leave to turn off all lights.

To help with implementation, it is suggested to:

- Maximize staff cooperation through education and awareness campaigns.
- Post signs in each room and stickers at each light switch.
- Make sure that security crews look out during their tours for lights that are not turned off when the office is vacant.

This step does not require any significant cost or hardware, and therefore has an immediate payback. A full implementation of this measure from a committed staff and management could reduce lighting electricity consumption by up to 20%.

LIGHTING EFFICIENCY MEASURES THAT RELY ON ADAPTIVE BEHAVIOR AND NOT HARDWARE ARE USUALLY THE LOW HANGING FRUIT WITH NO INVESTMENT AND POTENTIALLY LARGE SAVINGS.

A2) Separate task lighting and ambient lighting. Task lighting is a practice that facilitates particular tasks that require more lighting than is needed or provided for general or ambient illumination. It is also a good practice in workspaces that are only partially occupied. Separating ambient lighting from task lighting will give employees the flexibility to choose appropriate lighting levels for their workspace, improving lighting quality and reducing unnecessary lighting. Increasing available task lighting, for example through the use of desk lamps, and providing individual dimming and on/off controls will allow the users to control and balance the luminance ratios for their task.

Capital outlays involved are not high while the intervention is of medium complexity. However, it is important to involve a specialized consultant to recommend the necessary modifications to the existing lighting installations. Payback periods may be less than one year particularly in office spaces that are continuously lit.

A3) Train/educate staff to turn OFF unnecessary lights when office space is partially occupied. In many cases, lighting fixtures in a relatively large office space are controlled by one or two switches, which leads to large areas remaining lit unnecessarily when fewer staff are present. The absence of artificial lighting control flexibility can be addressed by making use of zone lighting to maintain lit only those work areas that are being used/occupied. The zoning of light fixtures by area into several circuits controlled by their respective switches facilitates the implementation of this practice. This intervention does not involve any significant hardware, and therefore has immediate payback. Savings could reach 10% of lighting electricity consumption. To help with implementation, it is suggested to:

- Maximize staff cooperation through education and awareness campaigns.
- Post signs and stickers in each zone (caveat: it is not economical to turn off fluorescent lights if room remains unoccupied for less than 15 minutes).

A4) Make use of daylight where possible. Day light that is admitted into the office space of a building via windows and skylights can sometimes be combined with artificial lighting to reduce overall lighting load. Although daylight is a far more efficient source of illumination than artificial lighting, the levels of available daylight vary throughout the day and the year. Daylight can also be uneven in a given office space, providing high illumination near the window and progressively poorer illumination as the distance from the window grows. Where possible, office managers can make use of daylight to supplement artificial lighting, reducing overall electricity draw for lighting while maintaining required illumination levels.

The quality and availability of daylight is governed by building orientation, brightness of the sky, shape and position of windows and skylights, and type of window shading. Making use of daylight often results in solar heat gain, which may or may not be desirable depending on the season. This intervention does not involve any significant cost or hardware, and therefore has immediate payback. Savings could account for up to 30% of lighting electricity consumption. To help with implementation, a schedule for daylight harvesting according to time of day and year may be set up based on the illumination levels required.

A5) Practice regular lighting maintenance. It is important to ensure that a regular maintenance and cleaning schedule is in place for existing lighting fixtures, reflectors, diffusers, and lenses. Dirty lighting fixtures experience up to 20% decrease in illumination performance. Keeping the lighting fixtures at optimal performance is an activity that practically costs nothing but could save energy. Keeping walls, ceilings, and floors free of dust, soot, and other dirt particles will definitely improve their reflectance, and hence increase illumination levels. When repainting, it is a good practice to use light colors to reflect more light. For the same working space, some 30% less lighting may be required if light-colored walls and furniture are utilized. Table 6.1 is a recommended lighting maintenance checklist for an office building.

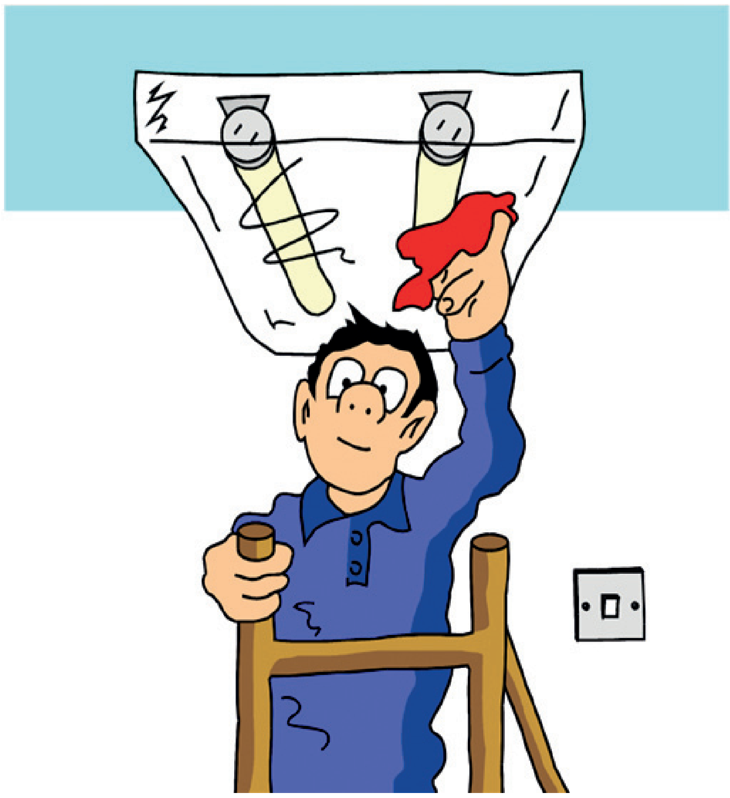


TABLE 6.1: LIGHTING MAINTENANCE CHECKLIST

ACTION	NOTES
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place.
Lighting use and sequencing	Turn off unnecessary lights.
Task lighting	Highlight the importance and efficiency of task lighting.
Use daylight	Make use of daylight where possible.
Replace burned out lamps	Replace flickering and burned out lamps. Burned out lamps can cause ballast damage.
Perform survey of lighting use	Perform survey of actual lighting use to determine lighting needs.
Measure illumination levels	Where possible, reduce illumination levels to industry standards.
Clean lamps and fixtures	Lamps and fixtures should be wiped clean to assure maximum efficiency.
Clean walls, ceilings, and floors	Clean surfaces reflect more light.
Paint with light colors	When re-painting, use light colors to reflect more light.
Lens replacement	Replace lens shielding that has become yellow or hazy.

B) LIGHTING CONTROL EFFICIENCY MEASURES

Some lighting control devices, such as light switches, manual dimmers, and window blinds can be directly accessed and controlled by occupants, enabling them to control their lighting environment. Automatic devices, on the other hand, are designed to replace human action. Automatic control devices may include occupancy sensors, timers, and photo-sensors.

B1) Install time clocks to automatically shut off lights after hours. Installing time clocks to turn lighting on and off eliminates inefficiency of human error in lighting control. Time clocks are best utilized in spaces where occupancy patterns are regular and predictable.

A lighting specialist can provide guidance on which time clocks are appropriate for which types of spaces, but generally 24-hour time clocks can be used where occupancy patterns are similar throughout the week and weekend, whereas 7-day time clocks should be used in spaces with occupancy patterns that vary from day to day. Three-phase time clocks may be used to control lighting and HVAC simultaneously.

Payback period: Measures based on ON/OFF lighting switching are medium cost strategies of relatively low technical complexity and risks with around 2-3 year payback period depending on electricity rates, lighting operating periods, current indoor lighting schedules, and hardware pricing. For large projects it is advised to hire the services of an energy audit company or a lighting consultant. See table 6.2 for product and labor installation costs.

TABLE 6.2: COSTS OF TIME CLOCKS AND OCCUPANCY SENSORS

Technology	Materials[1]	Labor[2]	Total cost[3]
Time clock, 24-hour electro-mechanical	$45	$30	$75
Time clock, 24 hour digital	$65	$30	$95
Time clock, 7 day electro-mechanical	$55	$30	$85
Time clock, 7-day digital	$65	$30	$95
Occupancy sensor wall mounted 180º view	$55	$40	$95
Occupancy sensor ceiling mounted 360º view	$150	$50	$200

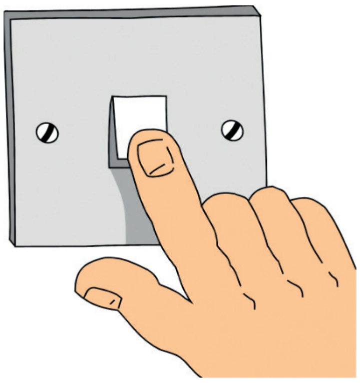
[1] Materials include device as well as ancillary accessories (enclosure, conduits, wiring, etc).

[2] Labor includes overhead and profits.

[3] Costs shown are representative for medium and high-income Arab countries. For Algeria, Egypt, Iraq, Sudan, Syria, Tunisia, and Yemen, reduce the total cost by 20%. Digital time clocks may not be found in the latter countries.

B2) Install 360 degree occupancy sensors with variable time setting. Occupancy sensors can save significant amounts of energy in spaces that are often unoccupied, or occupied unpredictably (stairwells, restrooms, conference rooms, etc). They are especially effective during hours of the night and early morning when offices have significant unoccupied space that does not require lighting. They are also used when human intervention is thought to be unreliable or a burden. To avoid performance problems, it is important that occupancy sensors be positioned correctly to respond to the movement or stillness of an individual anywhere in the space they serve. It is also important to maintain the ability to override the automatic controls, if necessary. Energy savings achieved by occupancy sensors vary from 13 to 80%, depending on the number and type of fixtures controlled, the frequency of occupancy, and the time span the lights are kept on when the space is unoccupied. Moreover, it is important to distinguish between occupancy sensors and motion detectors. The former detects presence even if the person is not moving, while the latter is triggered by movements. Typically, motion detectors are 40% less expensive than occupancy detectors. They have built-in timers that control their switching status. As a rule, spaces where people are not expected to remain relatively still such as storage rooms and staircases are better served with motion detectors, which could reduce the payback time.

The latest generation of occupancy sensors and motion detectors have built-in photosensors (see next section). Therefore, lighting circuits will not be energized even if people enter a space controlled by such devices if the level of day-lighting is above the adjustable set point.



Payback period: A feasibility study to install ceiling type occupancy sensors in the toilet rooms of a university campus in Hadath, Lebanon, has indicated a payback period of 2.6 years based on an estimated 3,000 operating hours, 50% energy savings, an average of 400 W installed lighting per toilet room, and an electricity cost of US$0.12 /kWh (this is the rate charged to public sector consumers by the national utility taking into account taxes).

B3) Install photosensors, dimmable ballasts, and dimming controls in indoor day-lit zones. Photosensors are electronic control units that automatically adjust the output level of electronic lights based on the amount of ambient light detected. In areas that receive varying amounts of daylight throughout the day, photosensor controls can adjust artificial light levels as necessary to supplement available natural light. A continuous dimmer controlled by a photosensor reduces artificial lighting by depending on daylight to maintain an optimum light level. Energy and cost savings will vary widely depending on natural light availability.

Electric lighting dimming controls, which can be either manual or automatic, not only reduce energy use, but they also provide flexibility. Instead of turning off all lights at any given time, lighting can be dimmed. Fluorescent lamps can be dimmed when fitted with dimming ballasts. Low-voltage tungsten halogen bulbs are dimmed with low-voltage dimming controls. Light-emitted diode (LED) lamps require a dimming power supply in combination with LED dimming controls.

Dimmable ballasts operated in conjunction with photosensors or other control devices achieve a gradual, controlled change in lamp output. Full-power artificial lighting is often unnecessary in areas that receive good natural daylight. Moreover, the same system could be coupled to occupancy sensors to shut off the lights in case of no occupancy.

This intervention involves high capital outlays especially if the actual lighting zoning does not take into consideration day lighting, which unfortunately is the case most of the time, leading to rather long paybacks that may exceed 8 years. Note that automatic dimming systems are hardly economical for small installations.

Therefore, the installation of photosensors with dimming controls and dimming ballasts is most cost effective when undertaken simultaneously with another lighting retrofit where ballasts and controls must be replaced. In this situation, the project cost is limited to the cost of the photosensor and controller installation plus the incremental cost of dimming ballasts and wiring over standard electronic ballasts. Since engineering expertise is required, retrofits should be undertaken only by expert contractors. The existing type of construction will impact the retrofit costs. For example, an exposed ceiling with flush mounted fixtures having embedded conduits will automatically imply high installation costs for a dimming system if the additional conduits for controls need to be also concealed inside the walls and ceiling.

Payback period: In a south facing open office space in Amman with a south glazed bay equipped with a 100 lighting fixtures 4x36 W type T8 linear fluorescent lamps. It is intended to install dimming ballasts and automatic dimming controls as alternative lighting retrofit to switching only from electromagnetic ballasts to electronic ballasts. This alternative would cost an additional $14,000 and would save $2,321 annually in electricity costs not taking into consideration the reduced air conditioning load, yielding an adjusted payback period of 8.3 years. The calculated payback period is based on a 42% reduction in drawn lighting energy due to dimming controls, 2,200 hours of operation per year, an electricity cost of US$0.12 //kWh (the utility rate for commercial consumers in Jordan), and material and labor costs as indicated in Table 6.3.

In the Gulf countries, a similar application would have yielded a payback period above 20 years due to very low electricity tariffs.

If a dimming system with pre-set illumination values was used without the photosensor, the payback period would be cut by half. However, such systems are burdensome because they will need to be manually reset according to the amount of daylight coming in.

TABLE 6.3: COSTS OF DIMMING BALLASTS AND CONTROLS

Technology	Materials	Labor[3]	Total cost[4]
Dimming ballast 36W	$45	$10	$55
Automatic Dimming system[1]	$2,500	$300	$2,800
Wiring per fixture[2]	$5	$7	$12

[1] Includes photosensor and controller for up to 150 lighting fixtures.
[2] Between controller and fixture. (Controllers can accommodate up to 150 fixtures 4x36 W).
[3] Labor includes overhead and profits.
[4] Costs shown are representative for medium and high-income Arab countries. For Algeria, Egypt, Iraq, Sudan, Syria, Tunisia, and Yemen, reduce total cost by 20%. Automatic dimming systems may not be readily found in the latter countries except Tunisia.

B4) Install time clocks or photosensors to control outdoor lighting. Energy savings can also be achieved through greater efficiency in outdoor lighting. Outside lighting circuits controlled by timers is most advisable when lighting is preset according to a daily or weekly schedule. Time clocks or photosensors that turn outdoor lighting on at dusk and off at dawn are of straightforward application and can avoid energy waste from unnecessary lighting.

Payback period: Energy and cost savings will vary greatly depending on current outdoor lighting practices. Timers involve low expenses and short payback periods of a few months especially when timers control several high capacity lighting fixtures. For product and labor installation costs, see Table 6.4.

TABLE 6.4: COSTS OF PHOTOSENSORS AND TIME CLOCKS

Technology	Materials	Labor	Total cost
Outdoor photosensor	$30	$20	$50
Time clock, 24-hour electro-mechanical	$45	$30	$75
Time clock, 24 hour digital	$65	$30	$95
Time clock, 7 day electro-mechanical	$55	$30	$85
Time clock, 7-day digital	$65	$30	$95

C) LIGHTING SOURCE EFFICIENCY UPGRADES

Upgrades to more efficient lighting sources (i.e., lamps, light fixtures, etc.) often yield the most significant efficiency gains in lighting systems. Look for opportunities to replace lighting sources (e.g., incandescents, T12 linear fluorescents) with modern, more efficient sources (e.g., compact fluorescent lamps, T8 or T5 linear fluorescents, LED, HID). For background information on lighting types, consult Appendix A: Lighting background information.

The cost of installing upgraded hardware such as improved light bulbs and switching controls is often modest but may require sometimes rather large capital outlays with a large spectrum of payback periods and technological complexities, thus providing a wide range of available options.

C1) Replace T12 by T8 or T5 linear fluorescent lamps. T8 or T5 linear fluorescents (T5 is narrower in diameter, somewhat shorter and more efficient than T8 linear fluorescents) are the standard lighting sources used in recently constructed office spaces. In offices 20 years and older, inefficient T12 lamps may still be in use. However these lamps are being currently phased out by manufacturers and may be difficult to find in most Arab countries; an upgrade to T8s or T5s should be undertaken in such offices.

T12s linear fluorescents use magnetic ballasts while T8s use either electro-magnetic or electronic ballasts. T5s operate solely with electronic ballasts. The respective ballasts of T12, T8 and T5 are not interchangeable, and therefore changing the lamp type will automatically involve changing the ballast. T8s and T12s come in the same standard lengths, so replacing a T12 with a T8 usually does not require a replacement of the entire fixture. The T5 is somewhat shorter than the T8 and the T12. This will require changing the complete fixture when switching from T12 or T8 to T5. See Table 6.5 for incremental product and labor cost of replacements when switching from T12 to T8 or T5.

TABLE 6.5: COSTS OF T8 and T5 LAMPS AND ELECTRONIC BALLASTS

Technology	Materials (incremental)	Labor (incremental)	Total cost
1219 mm T8 lamp	$0[1]	$0[2]	$0
1163 mm T5 lamp	$3[3]	$2[3]	$5
Electronic ballast	$17[4]	$3[4]	$20
Electro-Magnetic ballast[5]	$3	$3	$6
Complete T5 fixture 4x28W	$70[6]	$20	$90

[1] Lamp has no incremental cost over T12 lamp.

[2] Incremental labor cost is $0 with the assumption that T12 lamp is due to be replaced.

[3] Includes lamp holders, which need to be replaced if fixture is kept.

[4] The ballasts of T8 and T5, although different, have roughly the same price.

[5] If electro-magnetic ballasts are considered for T8 lamps.

[6] Electronic ballasts and lamp holder are included in the fixture price.

Moreover, 1219 mm T8 and 1163 mm T5 lamps with reflectors and electronic ballasts have about 20% and 30% higher efficacy, respectively, than similar length T12 lamps with magnetic ballasts, as illustrated in Table 6.6. The gain in efficacy when switching from T8 lamps with magnetic ballast to T5 lamps is around 20%. T5 and T8 lamps are less noisy, are lighter, and allow efficient dimming when designed to do so. They also have a longer life than T12 lamps, requiring less maintenance and producing less waste. Considering the gain in energy savings, it always makes sense to switch from T12 or T8 with magnetic ballasts to T5 even if it requires changing the lighting fixture, provided the original installation is more than 20 years old.

TABLE 6.6: T12, T8, and T5 EFFICACY[1] COMPARISON – 1219 mm LAMPS

Number of lamps	T12 lamps with magnetic ballast		T8 lamps with electronic ballast		T5 lamps	
	Input watts	Nominal System Efficacy[2] (lumens/watt)	Input watts	Nominal System Efficacy (lumens/watt)	Input watts	Nominal System Efficacy (lumens/watt)
2	94	71	75	84	58	94
4	188	71	150	84	116	94

[1] Efficacy: Amount of light output of a source per unit of input heat energy that source supplies to the space.

[2] Including ballast losses. Actual system efficacy at mid life is roughly 20% lower than nominal values for T12 and 10% lower for T8 and T5.

Because T5 and T8 lamps have a greater lighting efficacy (measured in lumens per watt), the same quality/brightness of light could be accomplished with fewer bulbs following a T12 to T8 or T5 retrofit, but this is not always the case as the example below will show. An additional benefit of delamping in warm climate countries is reduced heat produced from lamps, which lowers building cooling load and energy costs.

Payback period: In an office in Tunis, 100 4x40 W 1219 mm T12 fluorescent fixtures are to be upgraded with several options in mind as follows:

- Option 1: Upgrade to T8 with magnetic ballasts.
- Option 2: Upgrade to T8 with electronic ballasts.
- Option 3: Upgrade to T5 without changing fixtures.
- Option 4: Upgrade to T5 with changing fixtures.

Table 6.7 displays the costs, annual savings, and payback period for each option. The calculations are based on 2,200 hours of operation, a utility cost of US$0.12 /kWh (the utility rate for commercial consumers in Tunisia), and the data in Tables 6.5 & 6.6.

TABLE 6.7: UPGRADING FROM T12 TO T8 OR T5 WITH DIFFERENT OPTIONS

Option	Cost	Annual Savings	Payback period	Number of fixtures required
1	$2,400	$552	4.3 years	99
2	$8,000	$1,017	7.9 years	99
3	$9,600	$1,574	6.1 years	109
4	$11,600	$1,500	7.4 years	109

If the office was in Cairo, the payback periods would be at least 30% longer as the utility rate in Egypt for commercial consumers is US$0.08 /kWh.

It is worthwhile noting that no reduction in fixtures is possible for options 1 and 2, while for options 3 and 4 there may be a need to add lamps considering the reduced wattage of the T5 lamp, despite the increased efficacy of the fixtures (see Table 6.6). Consequently, it is always advisable to consult a professional firm to identify any trade-offs among different options.

If the office in Tunis was equipped with T8 fixtures with magnetic ballasts and it was suggested to upgrade to electronic ballast while keeping the lamps unchanged, the cost would be US$5,600 and the annual savings US$465 with payback of 12 years. Upgrading from T8 with magnetic ballast to T5 without changing the fixtures would cost US$7,200, yield yearly savings of US$1,022, and result in a payback of 7 years.

Permanently removing unnecessary light fixtures or delamping is also desirable if the lighting system is over-designed, leading to excessive illumination levels and unnecessary energy draw. If the installed lighting fixtures consist of fluorescent lamps, some of them can be disconnected. This intervention will incur some labor costs that are still minor, leading to very short payback not exceeding 2 months. It is necessary to check that illumination levels are acceptable after the intervention is completed. To minimize labor costs, it is a good practice to combine delamping, if needed, with other regular maintenance tasks such as the cleaning of lighting fixtures. Note that de-energizing fluorescent tubes by rotating them is not advisable because the ballasts of the disconnected tubes will still be connected to the power supply, therefore drawing electric current that will partly dissipate as heat losses on top of the fact that ballast life will be reduced.

C2) Replace incandescent bulbs with comparable compact fluorescent lamps (CFL). A typical incandescent bulb converts 90-95% of its energy input into waste heat. CFLs are designed to be compatible with traditional incandescent fixtures, but are 60-75% more efficient than comparable incandescent lamps and have an expected life of up to 10,000 hours vs. about 1,000 hours for an incandescent bulb. Replacing incandescent lamps with CFLs will save maintenance and cooling costs, in addition to reducing lighting energy costs.

CFLs come in a variety of shapes and sizes and can serve many different lighting needs. For example, variable-output CFLs feature three-way lighting outputs or dimmable lighting. CFLs are viable replacements for incandescent bulbs in almost all office lighting applications.

Payback period: Typical payback for replacement of incandescent bulbs with comparable CFLs is under six months. A sample calculation of estimated electricity savings resulting from replacing 100-watt incandescent light bulb with a 24-watt compact fluorescent light of comparable output in lumens is shown below.

PAYBACK PERIOD SAMPLE CALCULATION

for replacing 100 watt incandescent (INC) bulb with 24 watt CFL lamp

- Assumed operating hours per year: 1,500 hours (250 days @ 6 hours/day)
- Assumed electricity rate: US$0.08 /kWh
- Cost of CFL bulb: US$4
- Cost of INC bulb: US$1
- Annual CFL electricity consumption: 24*1500/1000 = 36 kWh
- Annual INC electricity consumption: 100*1500/1000 = 150 kWh
- Annual electric energy savings: 150 - 36 = 114 kWh
- Annual monetary savings: 114*0.08 = US$9.12
- Simple payback period: (4 - 1)/9.12 = 0.33 Years or 4 months
- Assumed primary/final energy conversion factor: 2.7 kWh/kWh
- Assumed power station CO_2 emission factor: 650 grams/kWh
- Primary energy saved at power station: 2.7*114 = 308 kWh
- CO_2 emission reduction: 308*650/1000 = 200 Kg CO_2

  The payback period calculated above is based on savings from reduced lighting electricity. The calculation did not take into consideration:
- The longer operating life of the CFL lamp.
- Additional savings from reduced cooling load and maintenance.

To determine which CFL bulbs will provide the same amount of light as current incandescent light bulbs, consult Table 6.8.

TABLE 6.8: EQUIVALENT WATTAGE OF INCANDESCENT BULBS AND COMPACT FLUORESCENTS OF COMPARABLE OUTPUT IN LUMENS

Incandescent bulbs (watt)	Minimum light output (lumens)	Compact fluorescent lights (watt)
40	450	9 to 13
60	800	13 to 15
75	1100	18 to 25
100	1600	23 to 30
150	2600	30 to 52

C3) Install light-emitting diode (LED) exit signs. Although exit signs draw a relatively low wattage, they run continuously. A typical incandescent exit sign has an annual energy draw similar to that of a desktop personal computer. LED exit signs are more energy efficient than incandescent or fluorescent exit signs. See Table 6.9 for a comparison of different light sources for exit signs.

TABLE 6.9: EXIT SIGN COMPARISON

	Incandescent	Fluorescent	LED
Input power (watt)	40	16	5
Annual energy (kWh)	350	96	18
Lamp life (years)	0.25-0.5	1-2	10+
Estimated energy cost per year (US$0.12 /kWh)	$42.0	$16.6	$5.30

Payback period: Replacing ten incandescent exit signs in an office in Beirut with ten LED exit signs was calculated to cost US$550 and save US$375 annually in electricity costs, resulting in a payback period of 1.5 years (assuming a cost of US$55 per sign, an electricity cost of US$0.12 / kWh, and a labor cost of US$5 /hour).

For an identical application in Algiers, the payback period would be roughly doubled, given the country's lower electricity tariff of US$0.07 /kWh.

C4) Upgrade outdoor lighting to high-pressure sodium fixtures or metal halide fixtures. High intensity discharge (HID) lamps provide energy savings of 50-90% over incandescent sources and are well suited to outdoor applications. HID bulbs have a longer life and provide more light per watt than any other light source. Increasingly, the more efficient high-pressure sodium and metal halide lamps are replacing mercury vapor lamps. Standard high-pressure sodium lamps have the highest efficacy of all HID lamps, but they produce a yellowish light. See Figure 6.10 for a comparison of the efficacies of different light sources. HID prices vary broadly depending on the application, but are generally significantly more expensive than comparable incandescent bulbs.

Payback period: Despite the high incremental cost of HID lamps, the wattage reductions achieved when replacing incandescent lamps with HID lamps are significant enough that payback is usually attained in less than a year.

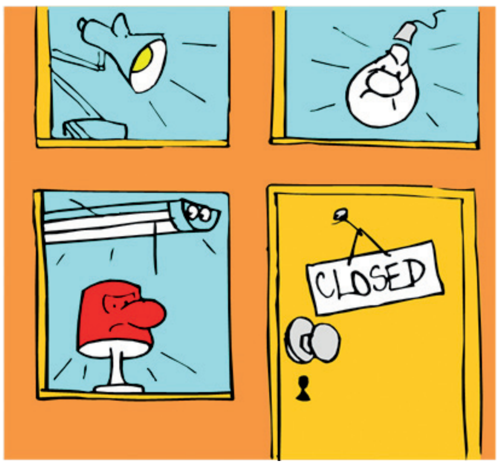
FIGURE 6.10: EFFICACY[1] (LUMENS PER WATT) OF VARIOUS LIGHT SOURCES

Source	Efficacy[2] (lumen/watt)
Candle	**1**
Oil Lamp	**0.3**
Incandescent Lamp (15-500W)	**8-22**
Tungsten Halogen Lamp (0-1500W)	**18-22**
Fluorescent Lamp (15-215W)	**35-80**
Compact fluorescent (CFL)	**55-75**
Mercury Vapor Lamp (40-1000W)	**32-63**
Metal Halide Lamp (70-1500W)	**80-125**
High Pressure Sodium Lamp (35-100W)	**55-115**
Induction Lamp	**48-70**
Sulfur Lamp	**90-100**
Direct Sun low altitude (= 7º)	**90**
Direct Sun @ high altitude > 25º	**117**
Direct sun mean altitude	**100**
Sky (Clear)	**150**
Sky (Average)	**125**
LED source	**130[3]**
Maximum theoretical limit of source efficacy (approximately)	**250**

[1] Efficacy: For a definition, see Table 6.6.

[2] Ballast losses are included in discharge lamps efficacy indicated in the Table.

[3] This value is being improved.



Additional information

Further information about lighting is available at:
http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

http://www.lrc.rpi.edu/researchAreas/controls.asp
Data collection about the number, type, and power consumption of various lighting fixtures in the office can be facilitated by using the checklist at:
http://www.med-enec.eu/sites/default/files/user_files/downloads/Checklist%205lighting.pdf

In a nutshell …

Tactics for reducing lighting energy use

1. Policy and process changes

- Train/educate staff to turn off lights.
- Separate task lighting and ambient lighting.
- Practice regular lighting maintenance.

2. Lighting control efficiency measures

- Install time clocks to automatically shut off lights after hours.
- Install occupancy sensors.
- Install dimmable ballasts and dimming controls in indoor daylit zones.
- Install photosensors in indoor daylit zones.
- Install time clocks or photosensors to control outdoor lighting.

3. Lighting source efficiency upgrades

- Replace T12 linear fluorescent lamps with T8 linear fluorescents lamps that have reflectors (for detail on lighting types, consult APPENDIX A: Lighting background information).
- Replace incandescent bulbs with comparable compact fluorescent lamps (CFLs).
- Install LED exit signs.
- Upgrade outdoor lighting to high-pressure sodium fixtures or metal halide fixtures.

CHAPTER 7 Office Equipment (PCs, Monitors, Copiers, Vending Machines)

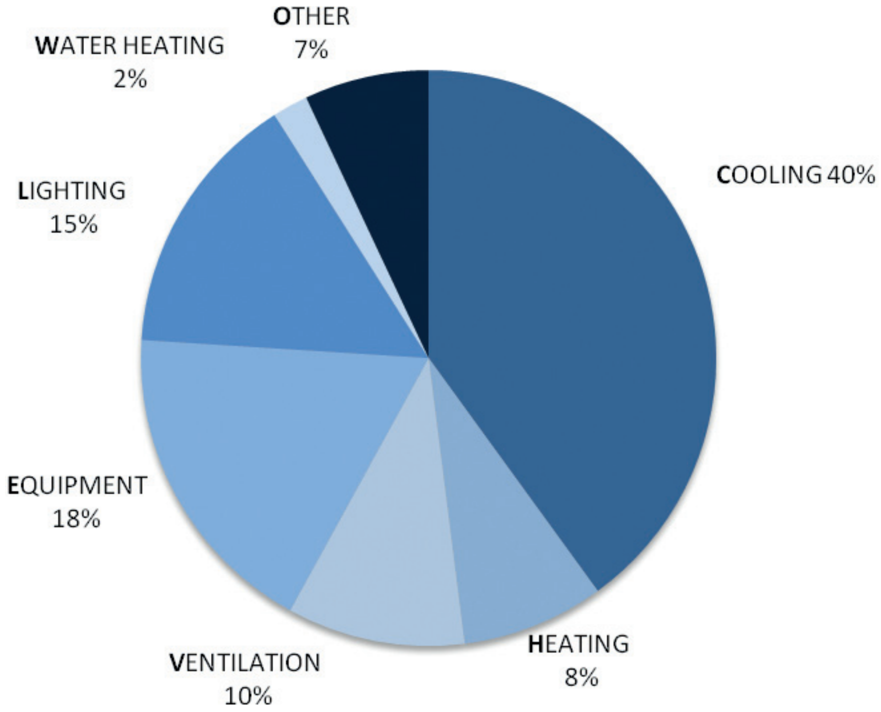
OBJECTIVES

- Develop an inventory of current office equipment and characterize their use patterns.
- Understand life cycle of office equipment from purchase/lease to initial configuration and ongoing maintenance.
- Develop estimates of energy usage by office equipment and calculate estimated savings potential of efficient-use technologies and office equipment upgrades.

OVERVIEW

On average, 18% of energy is used for office equipment in a typical large office building in the Arab region. For illustrative purposes, Figure 7.1 provides a hypothetical energy consumption breakdown in a large office building (>10,000 square meters). Waste heat from inefficient office machines can also increase a building's cooling load, which adds to the energy requirements of the HVAC system. Large potential exists to increase efficiency across office equipment, from personal computers (PCs), to copiers and vending machines, as illustrated in Table 7.2.

FIGURE 7.1: HYPOTHETICAL ENERGY CONSUMPTION BREAKDOWN IN A LARGE OFFICE BUILDINGS IN A GIVEN ARAB COUNTRY



This chapter presents a combination of strategies for reducing the power draw of typical office equipment. These strategies include increasing the efficient use of existing equipment and purchasing more efficient equipment. A number of relatively simple solutions can be implemented to reduce power consumption of existing equipment. Many offices in Arab countries have not yet taken up the simplest efficiency measures. Leaving desktop PCs on at night is a common practice. Of those computers, only a small fraction has power management settings activated to reduce their energy draw. Activating these power management settings is perhaps the easiest step that can be taken to reduce the energy draw of office equipment not in use. This can be accomplished by encouraging employees to enable power management settings on PCs, monitors, printers, and copiers. For PCs and monitors, installing centralized power management software that can automatically control individual power settings is a more comprehensive solution.

Because office equipment is typically replaced at shorter intervals than building systems such as lighting and HVAC, further reductions in energy draw can be made through the purchase of more efficient equipment. Energy certification, rating, and/or labeling programs, where they exist, set standards for efficiency in office equipment, providing a convenient way for organizations prioritizing efficiency in purchasing criteria to identify more efficient equipment.

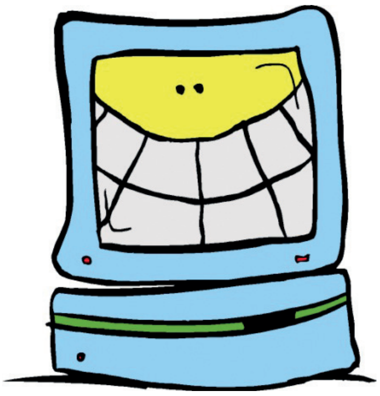
TABLE 7.2: ENERGY SAVING POTENTIAL AND STRATEGIES FOR TYPICAL OFFICE EQUIPMENT

Equipment	Average annual energy consumption (non-ENERGY STAR certified; without power management settings enabled) (KWh/yr)	Estimated Energy savings potential (kWh/yr)	Estimated energy savings potential percentage	Energy saving strategies
Desktop PC (60% left on at night)	520	~430	~83%	▪ Enable power-saving settings ▪ Install power management software ▪ ENERGY STAR-certified equipment purchase
Laptop PC	139	~5	~4%	▪ Enable power-saving settings ▪ Install power management software ▪ ENERGY STAR-certified equipment purchase
17-inch CRT Monitor	429	~350	~82%	▪ Enable power-saving settings ▪ Install power management software ▪ ENERGY STAR-certified equipment purchase
17-inch LCD Monitor	266	~180	~68%	▪ Enable power-saving settings ▪ Install power management software ▪ ENERGY STAR-certified equipment purchase
Monochrome Laser Printer (31-40 ppm)	1,164	~550	~47%	▪ ENERGY STAR-certified equipment purchase ▪ Use of duplex mode
Copier (21-40 ppm)	660	~360	~55%	▪ ENERGY STAR-certified equipment purchase ▪ Use of duplex mode
Vending Machine	3,468	~1752	~51%	▪ Install energy saving device (e.g., vending miser)

INFORMATION GATHERING GUIDE

The information technology (IT) manager should be able to answer computer-related questions. Other office equipment such as copiers and fax machines may be the responsibility of the facility or office manager. A campaign to improve the energy efficiency performance of office equipment should consider collecting relevant information. A list of commonly asked questions follows:

- How many desktop computers, laptops, copiers, printers, and vending machines are in use in the office? What percentage of each bears an energy efficiency label?
- What equipment is owned? Leased?
- If PCs do not carry an efficiency label, what is the timing of the next upgrade cycle?
- Who is in charge of the computer selection and purchasing decision process?
- What percentage of computers and monitors are turned off at night?
- What power settings, if any, are used on computers and monitors?
- Who is in charge of configuring and maintaining office computers?
- Has the company considered installing auxiliary computer power management software?
- Are the power save settings turned on for printers and copiers?
- Are printers and copiers sent to print by duplex by default?
- Who is in charge of office equipment policy changes?



TACTICS FOR REDUCING OFFICE EQUIPMENT ENERGY USE

Office equipment energy efficiency measures are divided mainly into those related to behavioral changes and policies, those related to more efficient use of existing equipment, and those that require upgrades and/ or replacement of hardware. The former includes usually no-cost or low-cost interventions while the latter may involve capital spending.

Until recently, people were not much concerned about the energy consumption of office equipment focusing instead on their functionality, processing performance, and productivity. At present, that attitude is changing and office equipment energy consumption is getting more scrutiny especially when equipment is in idle or standby mode.

A) EFFICIENT USE OF OFFICE TECHNOLOGIES

Efficient use of office technologies lowers the energy usage of existing equipment, typically by switching equipment to a low-energy state when not in use.

A1) Turn equipment off after office hours. This is the easiest and most straight forward measure available that produces significant savings at practically no cost. Studies have shown that more than 50% of all computers are not switched off after office hours (Robertson *et al.*, 2004). Avoiding complete shutoff of office equipment or worse yet leaving it on standby overnight may increase its energy consumption by no less than 70%, particularly if equipment has no power manager function or if this function is disabled. Shutting-off the power supply contributes to substantial energy savings with quick payback. It is also advised to shut off equipment if not used for long periods during office hours. To help with implementation, it is suggested to:

- Encourage staff cooperation through awareness campaigns.
- Post signs in each room.

COMPUTERS WITHOUT ENERGY MANAGERS FEATURES, IF LEFT ON STANDBY OVERNIGHT, MAY CONSUME 70% AS MUCH ENERGY AS DURING DAY TIME USE.

A2) Enable power management feature. Many modern computers and other office equipment, such as copiers, feature a Power Manager capability. However, in many instances users disable that feature when changing some settings on their machines. Studies have shown that no more than 25% of computers have their Power Manager features enabled (Robertson *et al.*, 2004). Power Management features — standard in Windows and Macintosh operating systems — automatically place monitors and computers (CPU, hard drive, etc.) into a low-power "sleep mode" after a period of inactivity. It is recommended to set computers to enter system standby or hibernate after 20 minutes of inactivity. To save even more, set monitors to enter sleep mode after 5 to 20 minutes of inactivity. Keeping a tab on the Power Manager settings will save energy at no additional investment. To help with implementation, it is suggested to:

- Encourage staff cooperation through awareness campaigns.
- Post stickers on the frame of desktops and other office equipment.
- Establish a monthly routine procedure by the IT department, to check power management settings on all office equipment and adjust accordingly.

A3) Install supplemental computer power management software. Centralized power management software sets power settings of all networked PCs and monitors to minimize energy waste. The software increases efficiency by allowing central controls to override individual user power settings. If company operations require that computers not be turned off at night, centralized power management software allows IT administrators to put PCs in a low power state and then power them up as needed (to install software, update virus definitions, etc.).

More information about power management is accessible at: *www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_low_carbon_join*

A number of power management software vendors will perform a free audit of network PC energy use and conduct an analysis of energy savings and payback time. Examples of power management software include EZ Save, 1E Nightwatch, SURVEYOR, and Policy Maker.

Payback period: Typical payback for purchase and installation of supplemental power management software on PCs is six months to one year.

A4) Install energy savings devices on vending machines or ask vendors to provide more energy efficient vending machines. Installation of a Vending Miser® or a similar device should be considered for each cooling-equipped vending machine. These devices manage both the lighting and the compressor in vending machines, and turn lighting on and off as necessary using a motion sensor. These devices reduce the energy consumption of vending machines about 50% on average, while maintaining proper temperature and necessary illumination**.**

Payback period: The cost of product and installation is about $195. Typical payback for the purchase and installation of energy saving devices on vending machines is between one and two years.

B) EQUIPMENT REPLACEMENT/PURCHASING

B1) Purchase energy certified PCs and servers with certified power supplies (converter cords) for PCs and servers. An energy efficiency labeled computer delivers substantial savings over a conventional computer. This applies to desktop, integrated desktop, and notebook (laptop) computers, workstations, small-scale servers, and thin clients. Make sure to identify any government-issued energy efficiency certification or labeling programs for computers. Nongovernmental or regional organizations may provide energy efficiency ratings. Globally, the most famous office equipment energy-labeling program is the United States Environmental Protection Agency (USEPA) ENERGY STAR, which is adopted by more than 20 countries. Information about the USEPA ENERGY STAR program is accessible at: *www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_efficient_equipment*

POWER MANAGEMENT SOFTWARE FOR COMPUTER NETWORKS PROVIDES THE GREATEST ENERGY SAVING POTENTIAL AMONG ALL OTHER ENERGY EFFICIENCY MEASURES APPLIED TO COMPUTERS.

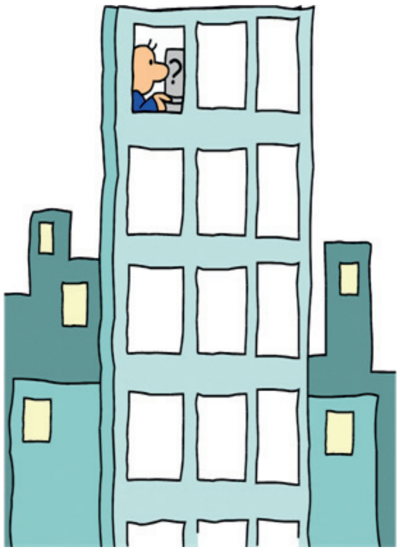
It is a worthy investment to procure energy-labeled power supplies such as the 80 Plus® that maintains high efficiency down to 20% load factors. The 80 Plus® performance standard requires that power supplies be at least 80% efficient at 20%, 50% and 100% of rated load. PCs with 80 Plus® certified power supplies are estimated to be ~33% more efficient than those without. The ENERGY STAR Version 5.0 specifications for desktop computers and Version 1.0 for servers, which went into effect in July 2009, require that PC power supplies meet 80 Plus® performance standards. A list of PC models with 80 Plus® certified power supplies can be accessed at: *http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx*

Costs: There is little to no incremental cost for ENERGY STAR certified PCs and servers. Savings calculators for ENERGY STAR office equipment can be accessed at: *www.energystar.gov/index.cfm?c=bulk_purchasing.bus_purchasing*

Uninterruptible power supply (UPS) can be a big source of energy wastage, if improperly sized. It is worthwhile to carry out a survey of the load factors of the different UPS in an office especially if a central one is installed feeding all office equipment and data centers. The efficiency of UPS and most other power supplies considerably decreases below a load factor of 25%; their adequate sizing contributes towards better energy efficiency.

B2) Replace CRT monitors with LCD. Liquid crystal display (LCD) monitors consume less than half the energy required by their cathode ray tube counterparts. The substantial drop in price over the past years has made LCD attractive for reducing energy consumption in offices.

B3) Purchase energy labeled imaging equipment (printers, copiers, scanners). Make sure to identify any government-issued energy efficiency certification or labeling programs for printers, copiers, scanners, fax machines, and any other imaging equipment. Nongovernmental or regional organizations may provide energy efficiency ratings. If a national labeling program does not exist in your country, make sure to consult the USEPA ENERGY STAR, which is adopted by more than 20 countries. ENERGY STAR printers, copiers, and monitors automatically switch to low-power standby modes after a period of inactivity. Imaging equipment models that meet the ENERGY STAR requirements are 40% more energy efficient, and feature efficient designs that help equipment run cooler and last longer. Overall, ENERGY STAR certified office equipment uses 30-75% less electricity than standard equipment. Information about the USEPA ENERGY STAR program for imaging equipment is accessible at:*http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=IEQ*



Payback period: There is little to no incremental cost for ENERGY STAR certified printers, copiers, and monitors. Savings calculators for ENERGY STAR office equipment can be accessed at:
www.energystar.gov/index.cfm?c=bulk_purchasing.bus_purchasing

B4) Purchase high-speed, duplex-capable laser printers, and make duplex printing the default print setting. Although high-speed printers draw energy at a higher rate, shortened printing time outweighs increased energy draw and results in less energy use per page printed. For example, a study has found that an eight page per minute (ppm) laser printer drew 60 watts, while a 24 ppm printer drew 100 watts. Because of the reduced printing time per job on the faster printer, however, average energy draw per print job was reduced by 40% on the 24 ppm printer.

Payback period: High-speed printers are generally priced higher than low-speed printers, but because they can handle larger print loads, fewer high-speed printers are needed to meet printing demand. Thus, especially when energy savings are accounted for, the net cost of high-speed printers tends to be lower on a cost/ppm basis.

Duplex printing reduces the cost of paper and paper disposal by up to half. A reduction in paper use will also lower the company's upstream greenhouse gas footprint. Make sure duplex printing mode is set as the default for all office internal document printing. For more information, see: *www.calculator.environmentalpaper.org/home*

Additional information

A Checklist of office equipment type and consumption measurement is available at:
http://www.med-enec.eu/sites/default/files/user_files/downloads/Checklist%203office%20equipment.pdf

An explanation of the checklist is available at:
http://www.med-enec.eu/sites/default/files/user_files/downloads/Checklist%203office%20equipment%20explanation.pdf

In a nutshell …

Tactics for reducing office equipment energy use

1. Efficient use of office technologies

- Turn Off equipment after office hours.
- Enable office equipment Power Manager feature.
- Install supplemental computer power management software.
- Install energy savings devices on vending machines or ask vendor to provide more efficient vending machines.

2. Equipment replacement/purchasing

- Purchase ENERGY STAR certified PCs and servers with 80 Plus® certified power supplies (converter cords) for PCs and servers.
- Replace CRT monitors with LCD.
- Purchase ENERGY STAR certified printers, copiers, and monitors, when replacing old equipment.
- Purchase high-speed, duplex-capable laser printers and make duplex printing the default print setting.

CHAPTER 8 HVAC (Heating, Ventilation, and Air-Conditioning)

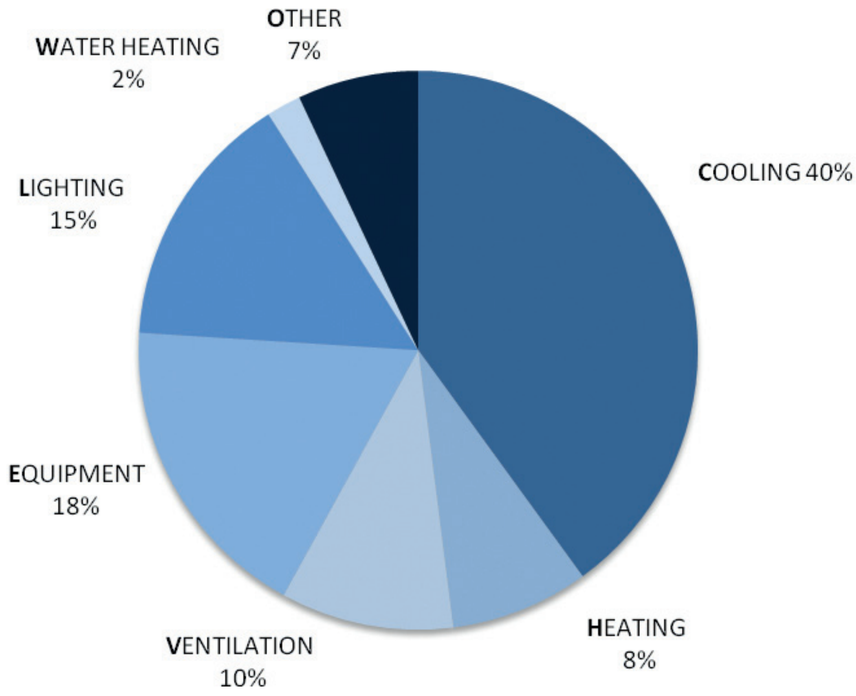
Objectives

- Survey current HVAC system(s), operating procedures, and maintenance schedule.
- Analyze results of energy audit for HVAC system(s) (performed by an HVAC professional) and identify effective energy efficiency improvements.
- Perform due diligence and conduct financial analyses based on the recommendations of energy auditors.

OVERVIEW

Building heating, ventilation, and air-conditioning (HVAC) systems are responsible for controlling temperature and humidity as well as circulating fresh air throughout a building. HVAC systems are relatively energy intensive and consume a significant portion of a building's energy consumption—51% on average in commercial buildings in the United States, 52% in Spain, 58% in the United Kingdom, 70% in Saudi Arabia, and 71% in Bahrain. Therefore, the HVAC system lends itself to the highest energy savings if properly audited. For illustrative purposes, Figure 8.1 provides a hypothetical energy consumption breakdown in a large office building (>10,000 square meters). The annual breakdown of HVAC energy draw among heating, ventilation, and cooling end-uses can vary widely depending on geographic location. It is not uncommon for larger buildings to require cooling year-round because of hot climatic conditions. Additionally, HVAC systems often operate at high levels during periods of regional peak load (for example, hot summer days) when electricity prices are highest, which can significantly increase a company's power costs.

FIGURE 8.1: HYPOTHETICAL ENERGY CONSUMPTION BREAKDOWN IN A LARGE OFFICE BUILDINGS IN A GIVEN ARAB COUNTRY



HVAC designs vary widely across building types. Standard HVAC systems are considered 'active' technologies, which require energy input to drive mechanical equipment. A typical HVAC system involves components including chillers, boilers, air ducts, fans, and heat exchangers. Alternative 'passive' cooling technologies are more rare, but typically much more energy efficient. These technologies include natural ventilation, evaporative cooling systems, and radiative heating and cooling systems. Care must be exercised to take a system optimization approach to component design and tuning.

A range of methods can be used to decrease the energy draw of an HVAC system, but one of the easiest is reducing a building's cooling load by reducing waste heat generated by inefficient lighting systems, office equipment, and water heating systems. These measures are extremely cost effective and should be undertaken before any upgrade to HVAC equipment is considered. If HVAC equipment has recently been upgraded to an efficient model, maintaining system performance at the proper level of efficiency should be a primary consideration.

Like lighting quality, HVAC performance is key to the comfort and productivity of building occupants. In fact, many HVAC efficiency upgrades have the added benefit of improving air quality and comfort throughout a space (e.g., precise tuning of thermostat controls or installation of outside air economizers). An HVAC engineer should ensure that efficiency upgrades to an HVAC system do not cause any reduction in the quality of a building environment.

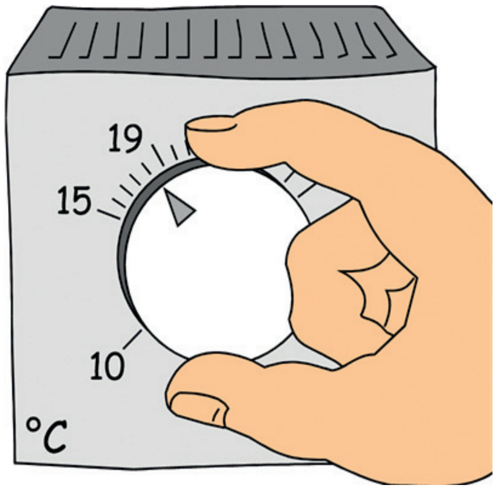
The recommended efficiency improvement strategies for HVAC are presented in the order in which they should be undertaken: 1) ensure that proper maintenance is being performed; 2) investigate possibilities for reducing heating/cooling load; 3) calibrate and tune system controls; and, 4) consider upgrading HVAC equipment. Efficiency improvements can be most cost effectively implemented in conjunction with the regular equipment upgrade schedule.

Note: Costs and energy savings for HVAC efficiency measures vary widely depending on building characteristics. In this section, examples of costs and savings potential are presented through financial case studies.

INFORMATION GATHERING GUIDE

A number of key questions are important to consider before addressing improved HVAC system function and efficiency:

- Does the office occupant own or lease the office space?
- Does the tenant pay the utility bill or is it included in the rent?
- Is the landlord (if not the host company) interested in pursuing efficiency improvements?
- What type of HVAC system is installed? Is the system unitary or centralized?
- When was the existing HVAC system installed?
- How do building managers control the HVAC system? Which controls are manual? Which controls are automated?
- Is there a planned preventative maintenance program for HVAC in place? Who conducts maintenance on the HVAC system?
- What data on building temperature and energy consumption does operations staff have access to? How are the data delivered, recorded, and tracked?
- What is the maintenance schedule for the HVAC system?
- Has the HVAC system undergone recent commissioning?
- What has been done to date to improve the efficiency of the HVAC system?
- Is the HVAC system about to undergo a scheduled upgrade or replacement?
- How is the indoor room temperature controlled: by office, zone, or floor?
- Is it possible for office occupants to open any office windows?
- Has feedback been collected about indoor climate comfort?



TACTICS FOR REDUCING HVAC ENERGY USE

When upgrading the HVAC system, it would be helpful to be aware of these general principles:

- A clear distinction should be made between energy conservation and energy efficiency: energy conservation should not be made at the expense of building occupants health and comfort.
- HVAC equipment should be in perfect working order and properly commissioned periodically.
- HVAC equipment capacities should match the load they serve.
- HVAC equipment should not be operated in non-occupied spaces.
- Recover wasted energy as much as practically feasible.
- Avoid using electric resistance heaters.

A) EFFICIENT USE OF HVAC TECHNOLOGIES (LOW COST / NO COST INTERVENTIONS)

Efficient use of HVAC technologies lowers the energy usage of existing equipment, typically by switching equipment to a low-energy state when not in use.

This category includes interventions that typically cost from US$0 to US$2,000 for a medium size office space of around 1,000 m^2 with paybacks of less than one year. Most of these rely on human interventions at the user and/or the operation & maintenance (O&M) levels, knowing that ultimately the main driver is management commitment towards energy efficiency. Even though at first sight these interventions seem benign and easy to implement, actual execution is not so obvious; results could be quite rewarding if a committed follow up is achieved.

A1) Turn off HVAC equipment when rooms are not occupied. This measure is most applicable when some kind of HVAC equipment such as a fan coil unit, a radiator, or an air handler is dedicated to a space. Another alternative would be to set the equipment on low operating mode if one knows that space will be occupied after a while. This measure underlines the importance of introducing system flexibility and modularity at the design stage. In many instances, a deficient design results in the necessity to keep a whole floor air conditioned because only one room is occupied.

The client role at the design stage is vital to ensure an integrated design approach is taken, where all stakeholders provide their input to make sure the resulting system fits perfectly the intended application. The rewards that could be reaped surpass by far the time and efforts invested in such an activity.

A2) Keep windows and external doors shut when HVAC equipment is operating. This may seem a trivial issue but surprisingly enough, is of quite common occurrence. Often doors and windows are left open as a result of a number of dysfunctional practices including in-office smoking, overcooling or overheating, and faulty ventilation. Overcooling or overheating can be caused by faulty zoning, faulty thermostat settings, or faulty system regulation and balancing. Often times, office occupants have different cooling or heating requirements. Faulty designs will be addressed below. To assist towards keeping windows and external doors shut, it is suggested to:

- Maximize staff cooperation through awareness campaigns.
- Post signs in each room.

A3) Increase summer space temperature settings and decrease winter settings. In many Arab countries, especially where the weather is uncompromisingly hot, people tend to favor extremely low space temperatures nearing 20ºC or even lower. Apart from being a cause of illness, such practices are a waste of energy especially for thermostat settings below 21ºC. Ideally, suggested office temperatures of 23-24ºC in the summer and 20ºC in the winter are easily achievable without any undue physiological discomfort especially when relative humidity is properly regulated. It is estimated that each 1ºC decrease in evaporator temperature may lead to 1-2% increase in energy consumption especially at low operating temperatures. It is a good practice to enclose the thermostat in a locked box.

A4) Make sure heat rejection equipment is properly aerated. Sometimes mechanical rooms and building roofs where HVAC equipment is located are used as storage spaces blocking the airways of condensers thus drastically decreasing their performance. It is estimated that on average each 1ºC in condenser temperature increase leads to approximately 1.5% decrease in equipment operating efficiency especially at high ambient temperatures as is the case in the Arab world.

A5) Keep radiators and fan coil units unobstructed. Do not use floor standing radiators and fan coil units as shelves to place books, files, or other items. Also do not place these units inside decorative casements that restrict air flow; such consoles could reduce the output capacity of radiators by up to 30%.

B) MAINTENANCE AND COMMISSIONING

The efficiency of existing HVAC systems can be maximized through a combination of regular in-house maintenance and periodic commissioning. In-house maintenance typically involves cleaning and replacing worn-out parts. Commissioning is a process by which equipment is tested to make sure it is performing according to design intent. Testing, adjusting, and balancing (TAB) are examples of commissioning tasks. Most commissioning services should be completed by professional technicians specialized in particular building systems.

B1) Regular maintenance of heat exchange equipment. This should involve:

i. Removal of deposit buildup from heating coils/chiller tubes.
ii. Cleaning and replacement of HVAC air and water filters: Clogged filters of air handlers cause a decrease in air flow which impact system performance and energy consumption. Moreover, dirty filters may be a breeding ground for bacteria.
iii. Boiler tune-ups.
iv. Checking steam traps for leaks.

B2) Commissioning. This should be performed by a specialized commissioning technician. A commissioning technician should:

i. Verify that HVAC system components are functioning correctly.
ii. Identify and correct any problems with the system controls.
iii. Ensure that the HVAC system is providing proper indoor air quality.
iv. Calibrate temperature sensors and controls to align with original design specifications.

Additional maintenance and commissioning activities are included in APPENDIX C: HVAC background information.

Financial case study: HVAC maintenance performed for a tower complex in San Jose, California, has resulted in tune-ups including modified boiler control programming, which cost $600 in labor and saved $41,779 in annual energy costs. An additional correction to the chilled-water pump controls cost $1,200 and netted $43,000 in annual energy savings.

C) Efficiency tune-ups

C1) Complete envelope upgrades. An energy efficiency engineer can evaluate whether upgrades to the building envelope can reduce heating/cooling load. Envelope upgrades include:

- Locating and sealing air leaks in windows, doors, roofs and walls. Eliminating infiltration due to air leaks in a large office building typically saves up to 5% of heating/cooling energy.

- Installing window films/shading. Window coverings block solar radiation from entering the building and reduce internal heat loss through windows by improving insulation. The typical cost for specialized high- grade window films that block heat and allow transmission of light is around US$3.00 per square foot. Window films have a typical lifetime of more than seven years.

Additional passive design practices and more detailed building envelope upgrades, including installing double-glazed windows and insulation, are discussed in Appendix D.

Financial case study: A property owner of a 1.4-million square-foot office complex installed 140,000 square feet of window film on floor to ceiling windows in San Francisco, California. The project qualified for efficiency incentives from the local electric power utility and reduced heating and cooling costs significantly. Taking the utility rebate into account, the project had a payback time of less than two years.

C2) Tune/install thermostat controls. An HVAC engineer should compare the host company building's heating/cooling patterns with its occupancy schedule to determine whether controls should be adjusted to reflect occupancy. Additional savings can be accomplished through the installation of combined automated control systems for HVAC and lighting (see Chapter 10, Energy Management Systems). HVAC and lighting can then be continuously monitored and adjusted based on occupancy and environment. An HVAC engineer should evaluate the feasibility of preheating or pre-cooling the building at night using off-peak electricity.

Financial case study: A property owner performed a modification of temperature and runtime settings of boilers in an office building costing

$400. The adjustments reduced the boilers' natural gas use by 20% for an annual savings of $42,960, representing an immediate payback on investment.

D) EQUIPMENT REPLACEMENT/PURCHASING

Full replacement of up-to-date HVAC systems is unlikely to be cost effective if undertaken solely to increase energy efficiency. However, many modern buildings are operating with outdated and inefficient HVAC systems. Upgrading an older system to a higher efficiency system should be considered, particularly if the building in question has experienced HVAC performance problems. In general, the property portfolio of an organization should be managed based on a life cycle approach and a capital plan. The office manager must be alert to take energy efficiency into account, when a capital project is planned for the HVAC system.

The principle objectives of HVAC upgrades are:

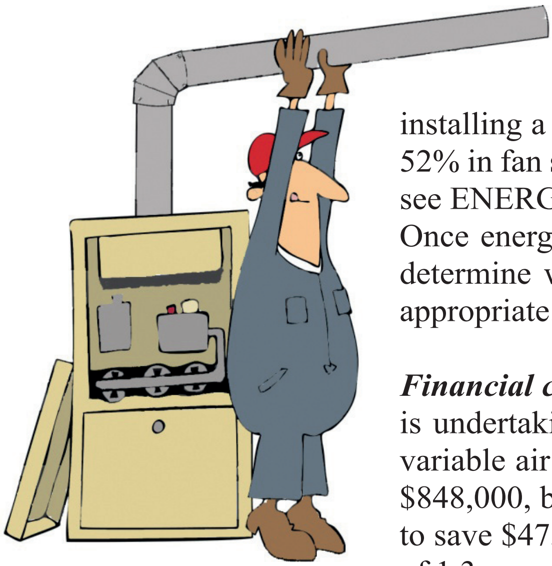
- Improved year-round occupant comfort and convenience.
- Higher energy efficiency with lower operational costs.

D1) Install outside air economizers. Air-side economizers use a damper to control intake of outside air. When outside air is cooler than return air, the damper adjusts to maximize air intake; when outside air is warmer, the damper reduces outside air intake to the minimum required in building codes. Air-side economizers can also be used to pre-cool buildings at night.

D2) Correctly size and retrofit HVAC fan systems. Fan systems (which distribute heated or chilled air throughout a building) are often more economical to replace than heating/chilling components. Fans are often oversized - a recent EPA study found that 60% of U.S. office buildings had fan systems that were at least 10% oversized, with an average oversizing of 60%. In general, correctly sizing a fan system results in a 50% decrease in energy drawn by the fan system.

Constant volume fan systems, which circulate a set volume of air and regulate temperature by heating or cooling air, are common in commercial buildings, but are relatively inefficient. Variable air volume (VAV) systems, which regulate temperature primarily by varying the volume of circulated air, are typically more efficient. Conversion from a constant volume system to a VAV system can reduce horsepower requirements for fans by 40-60%.

A VAV system can be retrofit to control fan speed using a variable-speed drive (VSD). VSD devices vary fan speed according to need, resulting in energy savings from reduced fan speeds. A recent EPA study found that



installing a VSD to an existing VAV system achieved a mean savings of 52% in fan system energy requirements. (For more information on VSDs see ENERGY STAR Building Upgrade Manual, p.107–108).
Once energy requirements of fans have been reduced, an engineer can determine whether downsizing a fan motor to a more efficient size is appropriate.

Financial case study: A 36-story high-rise in San Francisco, California, is undertaking a retrofit conversion of its constant volume system to a variable air volume system. The retrofit project will cost approximately $848,000, but will receive $179,000 in utility incentives and is expected to save $473,000 in annual energy costs, for an adjusted payback period of 1.3 years (see APPENDIX F: Case studies).

Financial case study: A variable frequency drive was added to the fan system in a tower complex in San Jose, California, enabling the system to adjust air volume and fan power to meet cooling load. The retrofit cost $126,960 and received a $63,500 rebate. Estimated annual energy savings are $78,000, representing a ten-month payback period.

D3) Measure existing heating/cooling loads and correctly size HVAC heating and chilling components. An HVAC engineer should re-measure heating and cooling loads to capture savings achieved through previous efficiency improvements and assess whether heating/chilling components can be downsized.

Generally, HVAC engineers will apply an "integrated system approach" to evaluating opportunities in heating and cooling systems. If heating systems and cooling systems are assessed separately, the process will be more time consuming and whole system efficiency upgrade opportunities may be missed.

D4) When feasible, replace outdated or highly inefficient HVAC systems. "Reheat systems," which cool and circulate a set amount of air and then reheat the cooled air as necessary to achieve desired temperatures, and "multi-zone systems," which mix cooled and heated air to produce desired air temperatures, are extremely inefficient. An HVAC engineer can consult on the feasibility of converting these types of systems to more efficient ones.

Financial case study: While renovating a 223,000-square-foot (six-story) office building in Encino, California, the property owner replaced an outdated chiller during an HVAC system retrofit. The 375-ton R-12 centrifugal chiller was near the end of its life, so a new chiller was required. The owner selected an energy-efficient Carrier 19XRV as a replacement, which has reduced annual energy costs by $15,500. After the receipt of a $15,750 utility rebate, the net cost of the chiller replacement was $273,884.

Additional information

A Checklist for collecting data about the heating status of rooms and windows in office buildings is available at:
http://www.med-enec.eu/sites/default/files/user_files/downloads/Checklist%20 4heating%20Status.pdf

An explanation of the checklist is available at:
http://www.med-enec.eu/sites/default/files/user_files/downloads/Checklist%20 4heating%20Status%20explanation.pdf

In a nutshell …

Tactics for reducing HVAC energy use

1. Maintenance and commissioning
- Turn off HVAC equipment when rooms are not occupied.
- Make sure heat rejection equipment is properly aerated.
- Keep radiators and fan coil units unobstructed.
- Verify regular maintenance schedule.
- Determine frequency of HVAC commissioning.

2. Efficiency tune-ups
- Complete envelope upgrades.
- Tune/install thermostat controls.

3. Equipment replacement/purchasing
- Install outside air economizers.
- Correctly size and retrofit HVAC fan systems.
- Measure existing heating/cooling loads and correctly size HVAC heating and chilling components.

CHAPTER 9 Water Heating

OBJECTIVES

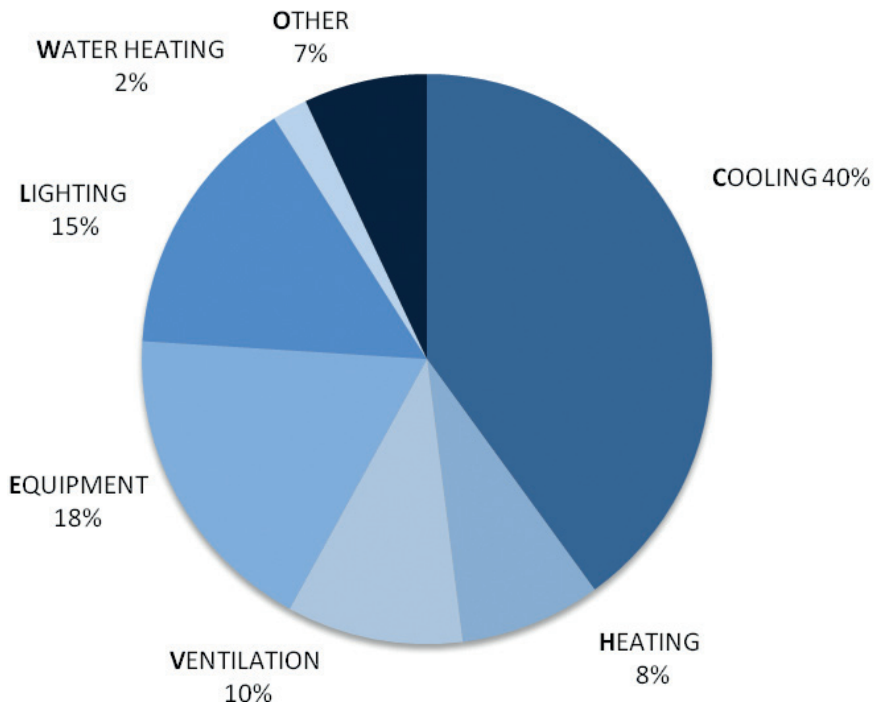
- Determine whether the water heating system is aligned correctly with office hot water requirements.
- Identify effective energy saving interventions that result in improved water heating efficiency.
- Develop estimates of water heating energy usage and calculate estimated savings potential of efficient use upgrades and heating equipment upgrades.

OVERVIEW

Many companies may be wasting money by heating water unnecessarily. Heating water at too high a temperature for daily applications and having an oversized water heater are both common wasteful practices. Like inefficient lighting and inefficient use of office equipment, inefficient and unnecessary use of water heaters releases waste heat that must be countered by increased cooling, resulting in additional wasted energy.

Water heating forms a very small fraction of energy consumption in offices, as illustrated in Figure 9.1. The energy costs of heating water tend to be low relative to the costs of HVAC and lighting. The share of energy used to produce hot water in the total energy budget of businesses in office buildings is estimated to vary between 0.5% for Arab countries mostly located in subtropical zones and 2.0% for countries in temperate zones. However, a business case can likely be made for many of the measures outlined in this chapter, most of which have no or low-cost. It is also important to note that companies often pay three times when they use heated water—with charges incurred for water use, energy, and sewage disposal. Therefore, measures taken to reduce heated water use will net more than just energy savings.

FIGURE 9.1: HYPOTHETICAL ENERGY CONSUMPTION BREAKDOWN IN A LARGE OFFICE BUILDINGS IN A GIVEN ARAB COUNTRY



INFORMATION GATHERING GUIDE

The facilities manager will most likely be the best source of information on water heating. Important questions to consider while looking at water heating efficiency improvements include:

- Who owns or operates the water heating equipment (the building operator or the leasing company)?
- Who is financially responsible for the water heating and how is it billed? How much does the leasing company spend on heating water annually?
- For what purpose is water being heated? What is the annual quantity of water heated?
- What types of water heaters are currently in use?
- What is the thermal efficiency of the existing water heater(s)?
- Does the building use central or distributed water heating equipment?
- What are the current temperature settings on the hot water heater(s)?

TACTICS FOR REDUCING WATER HEATING ENERGY USE

The measures outlined below can reduce the energy required to heat water and the quantity of waste heat released from tanks and pipes.

A) EFFICIENT USE ADJUSTMENTS AND UPGRADES

A1) Set water heater temperature appropriately. The factory temperature setting for water heaters is typically 60°C (140°F), but can usually be lowered to 49°C (120°F) (or lower) without affecting performance. An energy efficiency consultant can determine the appropriate temperature setting for a specific application. Another side advantage is reducing the amount of scale formed in the heating equipment. By one estimate, a switch from 60°C to 49°C can save 18% of water heating energy and a 5.6°C thermostat reduction can save 6% of water heating energy. Table 9.1 gives an estimate of temperatures required for a range of applications.

TABLE 9.1: HOT WATER TEMPERATURES REQUIRED FOR GIVEN ACTIVITIES

APPLICATION	TEMPERATURE	
	°C	°F
Hand washing	40	105
Showers and tubs	43	110
Commercial and institutional laundry	Up to 82	Up to 180
Residential type dish washing and laundry	60	140
Commercial spray type dishwashing-wash	65 minimum	150 minimum
Commercial spray type dishwashing-final rinse	82-90	180-195

A2) Install pipe and water tank insulation. Pipe and tank insulation reduces standby heat loss from hot water, reducing energy required to maintain the correct water temperature. Energy saved with pipe and tank insulation varies widely depending on application, but can be estimated for a specific building by an energy efficiency engineer.

Payback period: Consult with an energy efficiency engineer for an estimate of insulation installation costs and payback period.

A3) For electric heaters, install timers and heat water at night using off-peak electricity.

A continuously operating water heater during periods of low or no occupancy is a source of wastage. A timer could be installed to match heater operation to facility occupancy, by switching the heater off after office hours and re-energizing 1 hour before hours of operation.

Timers could also be installed to control hot water circulation, if used in an office building. By making hot water instantly available at the tap, hot water circulators save water but they consume electrical and thermal energy. Timers are an effective way to limit the energy consumption of

circulators. A good rule of thumb is to operate hot water circulators at equal 10-minute intervals.

Payback period: Consult with an energy efficiency engineer for an estimate of timer installation costs and energy savings. When calculating payback, it is important to account for savings due to off-peak electricity purchase. Payback periods vary greatly depending on specifics of the time-of-day power pricing structure.

A4) Install low-flow fixtures and automatic sensor controls. Lowering flow in hot water fixtures (faucets, showerheads, etc.) reduces the energy required to heat water by reducing the volume of hot water consumed. Use national guidelines established for maximum flow rate for faucets, showerheads, toilets, and other fixtures. Average flow rates for faucet aerators and showerheads are now around 2.5 gallons per minute (GPM). Super-efficient faucet fixtures have flows of 0.5 GPM, and super-efficient showerheads have flows of 1.5 GPM.

In addition to energy savings from avoided water heating, installation of low-flow fixtures and automatic sensor controls will result in savings from reduced water use. According to Greener Buildings, a resource center for environmentally responsible building, “in a typical 9,000-square-meter office building, low-flow fixtures coupled with sensors and automatic controls can save a minimum of one million gallons of water per year, based on 650 building occupants each using an average of 20 gallons per day.”

Payback period: Consult with an energy efficiency engineer for an estimate of low-flow fixture installation costs and energy and water savings. When estimating payback, it is important to account for savings due to energy and water savings.

B) EFFICIENT UPGRADES

Upgrading equipment will require substantial up-front capital investment and will therefore be easiest to justify financially when existing equipment is due or nearly due for replacement.

B1) Correctly size water heater for company needs. The leasing company may be operating with a larger-than-necessary water heater. An energy efficiency consultant can evaluate the heater size required to meet hot water demand. The hot water needs of a typical office building are: 0.4 gallons per person maximum per hour, 2.0 gallons per person maximum per day, and 1.0 gallons per person on average per day.

Payback period: Consult with an energy efficiency engineer for an estimate of costs and payback period for a water heater replacement.

B2) Purchase a water heater with higher thermal efficiency. Energy labeling programs are used to classify the thermal performance of water heaters. Some Arab countries, such as Tunisia and Saudi Arabia, have already introduced energy labeling systems for water heaters, while other Arab countries are in the process of doing so. When replacing water heaters, install new high efficiency heaters rated according to a national or international labeling system.

Efficiency of commercial water heaters is expressed as a thermal efficiency percentage (0-100%), which represents the percentage of energy from the fuel or electric heating element that is transferred to the water being heated (the higher the value, the more efficient the heater). Commercial heaters are also rated on standby loss, a measure of the percentage of heat lost per hour once water is heated. Standby loss is also expressed as a percentage, typically ranging from 0.5-2.0% (the lower the value, the more efficient the heater). Note: Residential water heater efficiency is expressed in a different unit: energy factor (EF), which ranges from 0.00 to 1.00 (higher values are more efficient). EF is a combined measurement of thermal efficiency and standby loss. For heat pumps, efficiency is expressed as a coefficient of performance (COP). But all these indicators relate to the same concept, they are the ratio of output energy to input energy including standby losses.

Typical oil and gas-fired heaters have thermal efficiencies of ~80%, but can reach up to 95%, as illustrated in Table 9.2. Gas-condensing water heaters are more efficient than traditional gas-fired heaters because they can increase thermal efficiency by up to 20%. Electric water heaters typically have a thermal efficiency of 98%. Whereas electric units themselves are very efficient, it is important to consider that the process of electricity generation and distribution is quite inefficient. The average thermal efficiency of power plants is around 33% (33% of input fuel energy is output as electricity). Additional efficiency losses occur during electricity transmission and distribution (9.5% on average in 2001). These inefficiencies contribute to the high price of electricity in relation to gas and oil in most markets. As a result, in most areas, oil and gas-fired water heaters have better economics and reduced climate impacts compared to electric water heaters.

In many applications, a tankless water heater may be the most efficient option. Tankless heaters heat water on demand instead of storing preheated water, which eliminates standby loss. An energy efficiency engineer can estimate potential efficiency gains from a switch to a tankless heater at the host company. Tankless heaters are typically more expensive than comparable storage type heaters.

Payback period: Consult with an energy efficiency engineer for an estimate of costs and payback period for a water heater replacement.

TABLE 9.2: TYPICAL EFFICIENCY VALUES FOR DIFFERENT TYPES OF WATER HEATERS

Heater Type	Final energy efficiency	Primary energy efficiency
Gas-fired conventional	80-90%	79-89%
Gas-fired condensing	95-98%	94-97%
Light fuel	80-90%	79-89%
Electric resistance	97%	29%

B3) Install solar water heaters (SWH). Using the incoming sun energy to heat water is an attractive option economically and environmentally that should be widely adopted. SWHs have made major inroads for residential use in many Arab countries. The adoption of SWH in office buildings would increase their scale and bring their costs down. Some Arab countries, such as Lebanon, offer financial incentives and grants to offset some of the upfront purchasing costs of SWH systems.

Payback period: The payback of such a system will not be lower than 4-5 years and will strongly depend on the source of energy being displaced as well as the market penetration of SWH in the country in question.

B4) Add water softener (if needed). Hard water accumulates scale on hot surfaces. Scale greatly reduces the rate of heat transfer between the heating medium and water in a hot water heater thus degrading heater efficiency. In a light fuel boiler, roughly every 1 mm of scale build-up reduces heat transfer by around 2%. To minimize scale formation, use water softeners.

Payback period: Water softeners dedicated to hot water heaters are not costly considering the relatively low hot water consumption in office buildings. A softener will have a payback period of 3-4 years for fuel-fired heaters. For electric heaters, consult with an energy efficiency engineer for an estimate of costs and payback period.

Additional information

Further information is available at:
American Council for an Energy-Efficient Economy (ACEEE) - *www.aceee.org*
Collaborative Labelling and Appliance Standards Program (CLASP) - *www.clasponline.org*
Global Ecolabelling Network - *www.globalecolabelling.net*

In a nutshell …

Tactics for reducing water heating energy use

1. Efficient use adjustments and upgrades
- Set water heater temperature appropriately.
- Install tank insulation.
- Install pipe insulation.
- For electric heaters: heat water at night using off-peak electricity.
- Install low-flow fixtures and automatic sensor controls.

2. Equipment upgrades
- Correctly size the water heater for company needs.
- Purchase a water heater with higher thermal efficiency.
- Install solar water heaters.

CHAPTER 10 Energy Management Systems (EMS)

Objectives

- Determine whether the leasing company can benefit from an energy management system (EMS) installation or upgrade.
- Develop the methodology for performing measurement, monitoring, control, and forecasting activities that are needed for the EMS.

OVERVIEW

This chapter addresses the need for an energy management system to measure, monitor, control, and forecast energy consumption in an office building, and ultimately to benchmark its energy performance. We also address the implementation of an operations and maintenance (O&M) program in the building.

An energy management system (EMS) allows for centralized monitoring and control of energy use across building systems. The upgrades to controls for lighting, office equipment, HVAC, and water heating that have been described in previous chapters all constitute "stand-alone" control systems (e.g., photosensor-based dimming controls for lighting); an EMS is a "central" control system, allowing facilities managers to operate all stand-alone control systems in a building simultaneously from a single control pad or web application. Sensors throughout the building that measure conditions such as light level, indoor/outdoor temperature, and water temperature (called "monitoring points") serve as data inputs for the EMS, which uses that information to adjust control components (called "control points") such as dimmers, chillers, and boilers. When a new EMS is installed, it can be configured to work with most existing sensors and controls, and to any new monitoring points and control points that are added. In recent years, EMS technologies have become more affordable and more widely used.

Building Management Systems (BMS) and Building Automation Systems (BAS)

Facilities managers and energy efficiency engineers may also refer to building management systems (BMS) or building automation systems (BAS). The distinction between these terms and EMS often depends on context or the preferred terminology of a given manufacturer, and can be confusing.

A BMS or BAS typically includes automated controls for a range of building systems: HVAC, security, fire alarms, sprinklers, etc. The term EMS is usually used to refer to an automated system specifically engineered to manage energy use, which usually employs additional and more sophisticated energy monitoring and control technologies than a BMS or BAS. However, some systems referred to as EMS can be configured to control other building functions in addition to energy management. Conversely, some BMS or BAS are designed to include sophisticated energy management technologies. As a result, the terms BMS, BAS, and EMS refer to an overlapping range of system types and are often used interchangeably.

Energy Information Systems (EIS)

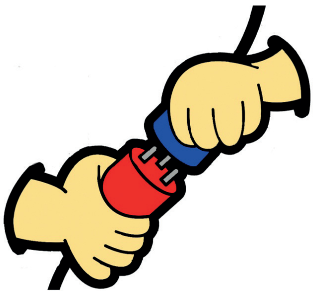
Most EMS have the capability to record and track the real-time energy usage of a building or floor, and to store that information for later analysis. Increasingly though, energy information systems (EIS) are being used to supplement the energy monitoring and tracking of EMS with functions including weather information, pricing structures, and more sophisticated real-time energy usage data. An EIS can enable a company to further reduce energy costs by integrating factors such as weather and energy prices into energy management decision making. An EIS also enables companies to participate in utility load curtailment programs, where utilities incentivize end users to reduce energy consumption during periods of peak demand.

INFORMATION GATHERING GUIDE

Information should be gathered from the host company's facilities manager, and consideration should be given to whether a building can benefit from an EMS installation or upgrade.

Questions for the host company's office or facilities manager

- Does the leasing company currently use an energy management system? If so, when was it installed?
- Does the leasing company currently use an energy information system?
- What is the building/floor's current peak demand?
- Does the leasing company currently participate in a utility peak load curtailment program? If so, what has the company's experience been? If not, has the company considered participating in such a program?
- Does the facilities engineer feel that building efficiency would benefit from increased automation of systems controls? What portion of efficiency controls is currently being controlled manually?



Questions for an EMS installation engineer

- Is the leasing company's building a good candidate for a new EMS installation or EMS upgrade?
- What is the range of options available in terms of system sophistication? What are the estimated savings potentials and installation costs associated with each of these options?

- What sensor and control points does the leasing company's building currently employ? Can an EMS be configured to interface with existing sensors and system controls?
- What additional sensor and control points would improve EMS performance?

Energy to a facility flows in different forms as it gets transformed from *final energy* such as electricity, diesel fuel, natural gas, and pumped municipal water to *useful energy*, thus providing illumination, comfortable air temperatures, high standard air quality, and hot water, as well as the running of office equipment such as computers, copiers, and printers.

This transformation from *final* to *useful* energy is undertaken by building services such as lighting systems, HVAC system, office equipment, and others covered in this handbook.

Our first step would be to measure the input energy to, and in most cases the output energy from these systems with the aim to establish an energy balance or an energy budget for our facility which allow us to quantify the third component of the energy triad in a facility namely *wasted* energy.

A) EMS OPTIONS

A1) New EMS installation/retrofit upgrade. Energy management systems range broadly in complexity. More complex systems have greater numbers of "points"—monitoring points (inputs) and control points (outputs)—which typically translate into higher energy saving potential, as well as higher installation costs. More complex systems are more fully automated and require minimal manual adjustment by building operations staff once the systems are operational.

According to the California Energy Commission, any building with a peak demand over 200 kW should consider employing an EMS. Additionally, if an existing EMS is over 12 years old, full system replacement should be considered. If a host company currently employs an EMS that has been installed within the last 12 years, it may be advantageous to undertake a retrofit upgrade to a more sophisticated system. A retrofit upgrade can often be accomplished by installing and connecting additional sensor and control points to the existing EMS system and reprogramming the software to incorporate the added equipment. An EMS specialist can advise on the feasibility of retrofit upgrades.

Selecting the correct system for a given building requires considering the needs and capabilities of the company's operations staff. Clearly, a company should not invest in a system with features it is unlikely to fully utilize. The best EMS for a given company is the system that maximizes energy savings potential per dollar invested. An EMS specialist should present a range of installation or upgrade options accompanied by estimates of energy savings potential and installation costs. These estimates, along with knowledge of host company needs, can provide the basis for analysis of whether an EMS installation or upgrade is worthwhile and what level of system is best for the company.

Payback period: The cost of an EMS installation or upgrade varies greatly depending on the number and type of sensor and control components installed. Table 10.1 provides a rough estimate of the cost of new systems of varying degrees of complexity. Upgrades typically cost approximately US$500 per point.

TABLE 10.1: EMS SYSTEM COMPLEXITY LEVELS AND COSTS

Systems complexity level	Control components	Average costs per control point
Static	Packaged units and chiller start/stop control based on time and temperature; fan and possible lighting on/off control based on time; and/or water temperature control based on time and temperature.	$200
↓	Static plus: Introducing modulation control; Economizer controls; chiller plant controls; variable-speed drive control; night temperature control; CO_2 ventilation strategies; and/or lighting control strategies.	$400
Dynamic	Plus: Reduced human intervention; Optimal start/stop; demand limiting strategies with hierarchical logic; daylight modulating controls; thermal storage controls; and/or optimizing HVAC operations.	$700

Financial case study: In 2002, a company moved into a new 67,000-square-foot headquarters in San Francisco. The existing building management system (BMS) was 20 years old and in need of replacement. The company installed a new Emcor BMS with timed start-up and shutdown for lighting and HVAC. The new BMS system also allowed the company to track energy use on each floor separately (sub-metering) and to charge the groups using each floor their true portion of the energy costs. The BMS installation cost $40,000 and reduced electricity and gas costs by 50%, achieving a 1.7-year payback period for the project.

Financial case study: Until 2001, the 1.4-million-square-foot Hewlett Packard (HP) campus in Roseville, California, was operating an EMS with limited automation, which required labor- intensive manual adjustment of controls in order to curtail energy loads during peak demand events. Using funds available from the California Energy Commission and the local municipal utility (Roseville Electric), HP upgraded its EMS and added additional sensor and control points for ventilation and lighting systems. The changes gave HP the capability to shed 1.5 MW of its 10.9 MW peak demand without disrupting occupants. HP now uses the EMS load-shedding capabilities on a day-to-day basis, saving $1.5 million annually in energy costs as a result. The EMS upgrade cost $275,000, but incentives covered $212,000 of the project cost, giving HP a payback of less than one month on the project.

Most of the control functions required to implement the energy efficiency measures described in the previous chapters could be performed by the EMS. A list of the most relevant control functions follows:

- Lighting modulation for daylight control.
- Timers for lighting control.
- Load shedding, demand side management for peak load shaving.
- Offset cooling.
- Space temperature set point based on the outside temperature.
- Chiller variable speed control.
- Economizer mode enabling.
- Free cooling.
- Night ventilation.
- Timers for electric water heater control.

B) Building energy program

B1) Install instrumentation to measure energy and water consumption.
In order to come up with an accurate energy and water consumption profile for an office building, some critical data measuring capability is required. The following is a recommended listing of the instrumentation that should be *permanently* installed in the facility. Whether readings are performed by operators or automatically sampled through an automated system will be addressed in the next section.

a. Water meters

- Municipality and/or well water supply lines to the building (if applicable).
- Discharge lines from softeners and reverse osmosis systems.
- Main domestic cold water line.
- Main domestic hot water line.
- Main potable water line.
- Make-up line feeding cooling towers.
- Make-up line feeding steam boilers.
- Main irrigation water line.

b. Energy meters

- Across the water-side of chillers, evaporators, and condensers.
- Across each steam and hot water boiler.

- Across each solar hot water heating system.
- Across heat recovery equipment such as heat recovery steam generators.

c. kWh meters
- For each main distribution board.
- For each lighting and auxiliary power panel board above 20A rating.
- For each electrical equipment above 5 kW rating.

d. Fuel/gas meters
- For facility kitchen equipment.
- For each generator.
- For each boiler.

e. Run hour meters
- For each electrical equipment above 5 kW rating.
- For each air handling unit.
- For each boiler.
- For each water treatment unit.

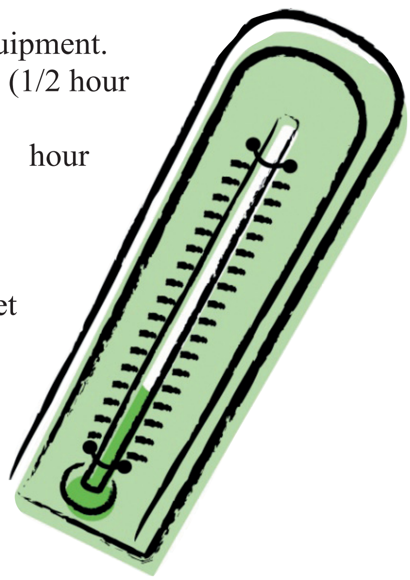
Run hour meters are a key component in any energy monitoring and verification program and are therefore essential.

f. Flow/mass meters (this function could be provided by the energy meter)
- Chilled and hot water in main lines.

g. Temperatures (this function could be partly provided by the energy meter)
- Approach temperatures for chillers, evaporators, and condensers.
- Boiler supply temperature.
- Air handling units air supply and return temperatures.
- Air handling units supply and return temperatures across chilled and hot water coils.
- Temperatures across heat recovery equipment.
- Space temperature for important areas (1/2 hour sampling).
- Outside ambient temperature (1/2 hour sampling).

h. Pressures
- Across each pump and booster set above 0.5 kW.
- Steam boiler outlet.

i. Relative humidity
- Space relative humidity.
- Outside relative humidity.



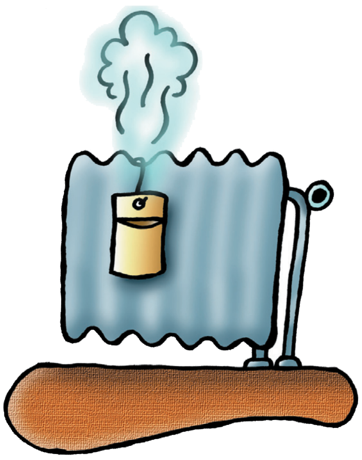
IMPORTANT

Make sure to:

- Install flow meters as per manufacturer instructions to ensure proper and accurate data readings.

- Calibrate the measuring instruments at predetermined intervals. The accuracy of instruments is critical for a sound energy management program. Flow meters should particularly be maintained regularly to ensure accurate readings, as they are the main source of errors in a data monitoring system.

Automation vs. human intervention: The extent of automated vs. field readings is a management decision that depends on the availability of skilled manpower, costs, the required complexity of the contemplated EMS, budgeted capital outlays versus operating costs, and finally the capabilities of the existing O&M team.



Ideally, automated readings, logging, and data storage for further processing should be targeted whenever the allocated budget allows. Doing so would minimize human reading errors and preclude the possibility of missed data collection. If an EMS is used to handle automated measurements, care should be taken to make sure that the system has enough data storage capacity and ability to transfer data to storage banks for further processing. Figure 10.1 illustrates the trade-offs involved in automated vs. manually operated energy system.

FIGURE 10.1: EMS SYSTEM CONFIGURATION

Low capital costs High operational costs	MIXED APPROACH	High capital costs Low operational cost

Manual start/stop of equipment	**Fully automated operation**
Manual data recording	**Automatic data logging**
Manual performance computations	**Software based evaluation**
Manual Book keeping	**Binary data storage**
Manual scheduling of Maintenance activities	**Software based scheduling**

In general, for large and even medium size facilities with an office space exceeding 1,500 m^2, partial automation of the EMS is strongly recommended. It is doubtful that the existing O&M team will ever be able to cope with such a task manually.

B2) Hire an environmental performance officer or a certified energy manager. One key person central to the process of implementing an EMS is the *environmental performance officer* (EPO) for the building. The EPO's main duties will be to manage monitoring, control, verification, forecasting, and benchmarking of the building's energy performance.

The position's title suggests responsibilities that go beyond energy management, encompassing other aspects of a building's environmental performance. However, energy issues are central. The position's title also denotes the increasing importance of environmental concerns in the day-to-day operation and maintenance of office buildings.

It is highly unlikely today for a large building to be able to implement an energy management system without the involvement of a capable and dedicated manager/officer fully committed to the project, with deep knowledge of energy and water management in medium to large office buildings. The box below sets the terms of reference for such a position.

Environmental Performance Officer
Scope of Work

The party to occupy this position should be preferably a full time staff reporting directly to top management. The environmental performance officer should be given decision-making authority to allow the satisfactory performance of the scope of work detailed below.

Professional capabilities required

- Excellent managerial and team work abilities.
- Extensive engineering knowledge and experience in building services systems.
- Extensive experience in energy saving schemes for building services systems.
- Experience in resources and waste management programs.

Mission

Promote and implement effective, efficient as well as responsible practices that achieve resource efficiency, particularly concerning energy and water.

Scope of work

- Establish in cooperation with building directors annual energy and water consumption targets as well as carbon reduction commitments using baseline data and facility projections.
- Develop and publish a 3-year strategy with reference to the targets mentioned above in line with relevant best practices and legislative requirements.

- Identify and review suitable methods for auditing, reporting, and benchmarking of the energy performance of the building.
- Develop a carbon accounting methodology.
- Communicate energy efficiency initiatives to the stakeholders in a building and promote behavioral change.
- Supervise all energy data measurement, logging, and processing.
- Decide which systems will be equipped with energy data monitoring instrumentation.
- Monitor electro-mechanical (E&M) systems energy performance.
- Issue directives to correct faulty practices in E&M systems operation that lead to wastage.
- Verify that established resource consumption reduction targets have been met.
- Investigate measures to further reduce energy consumption.
- Undertake sustainability performance auditing.
- Establish energy performance benchmarks.
- Ensure that the building complies with all current environmental laws and regulations.
- Provide strategic direction to improve the building's social and environmental responsibility performance.

B3) Conduct energy audits. Any business, irrespective of how successful and well-staffed, always needs a new pair of eyes and a discerning mind to take a closer look at its operations. As the saying goes, familiarity breeds inertia, contempt, and a loathing to change. Energy management is no exception to that inescapable rule.

Even in firms where energy efficiency is deeply ingrained in their culture need to perform an energy audit by an independent party every once in a while to assess its energy consumption performance. Consult energy audit best practices published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Chartered Institution of Building Services Engineers (CIBSE).

B4) Set up an effective operations & maintenance (O&M) program. A prerequisite for good energy management in any building is an effective O&M department. In fact, investing in an O&M upgrade is one of the most lucrative energy saving measure undertaken by any building administrator/manager. There are four O&M issues that are most critical to shaping up the operating efficiency and effectiveness of a building.

i. Operations & maintenance (O&M) program: A pre-requisite to energy efficiency in any building, irrespective of its size, is a properly thought out O&M program implemented by an adequately sized, professionally qualified and motivated team. This requirement becomes critical for relatively large buildings, operating sizeable, multi-million dollar equipment, and consuming large amounts of energy and water.

The central core of O&M activities revolves around a highly efficient computerized maintenance management system with a first rate software to optimize O&M activities, effectively managing day to day and longer term operations including:

- Preparing an O&M budget.
- Conducting preventive maintenance activities based on equipment manufacturer recommendations.
- Keeping an operational history database for the different equipment.
- Keeping spare parts and vendor inventory.
- Addressing demand maintenance requests in a timely manner.
- Processing material request forms.
- Processing work orders.
- Processing material receiving vouchers.
- Supervising maintenance intervention actions on equipment.
- Facilitating coordination between the O&M personnel.

Buildings face considerable costs due to operating inefficiencies and energy wastage that is often not directly perceived in relation to deficient O&M practices. Such misperception delays urgent and compelling action to take corrective measures by management. Swift and focused interventions often result in considerable savings in operating expenses.

ii. O&M personnel: The best O&M programs are ineffective if the personnel in charge of implementing them do not have the necessary qualifications and know-how. O&M personnel should be given the necessary administrative and technical tools that permit them to properly perform their duties. Investments in O&M personnel should target:

- Capacity building on a continuous basis.
- Awareness about the importance of energy efficiency.
- Empowerment.

iii. Availability of technical information: Technical information such as O&M manuals, as-built drawings, equipment schedules, and single line diagrams for the different electro-mechanical (E&M) systems should be accessible to the O&M team.

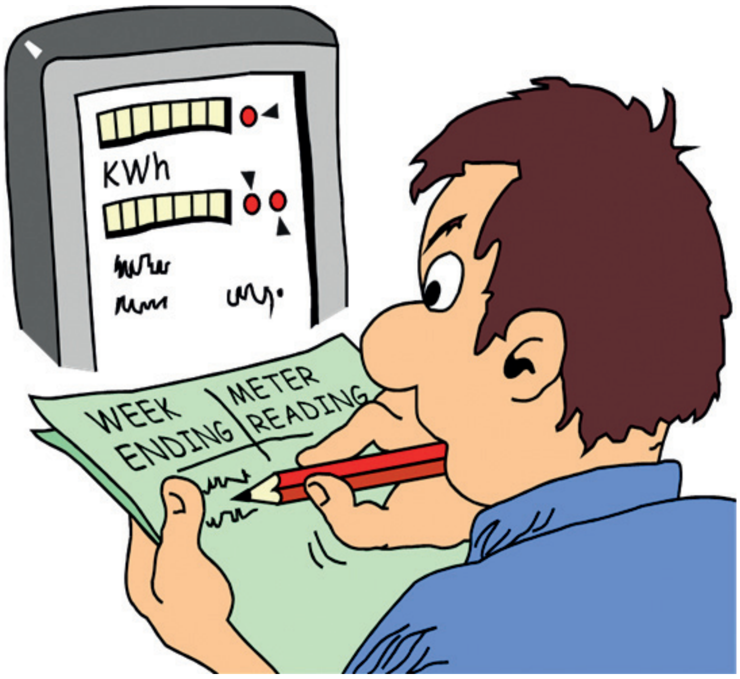
A considerable amount of time could be wasted trying to source out the necessary information to be able to proceed with O&M activities if this documentation is not available. O&M teams of modern facilities should have at hand the necessary technical information to properly perform their tasks. All O&M personnel should be familiar with the E&M systems they operate. It is therefore important to ensure that the following is available to the technical staff:

- O&M manuals for all existing E&M systems at the facility.
- E&M Equipment schedules.

- Single line diagrams for all E&M systems.
- Mechanical rooms layout.
- Proper training on the existing equipment being operated.

iv. Data logging and equipment log sheets: This activity should be coordinated with the facility EMS capabilities. Equipment operating parameters that are not monitored by the EMS like kWh (kilo Watt-hour), operating temperatures, and hour meters should be manually logged by the O&M team. The aim is to record the operating history of the equipment in order to monitor changing trends in their operating parameters that are vital for a preventive maintenance and energy management program.

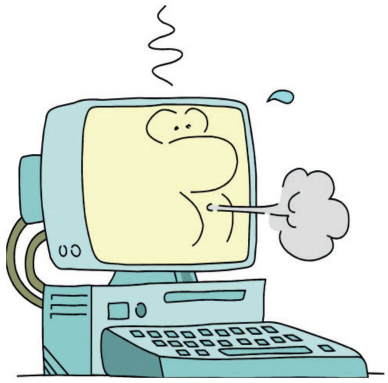
Log sheets should be assigned to each piece of equipment to monitor all periodic maintenance activities. Make log sheets for pumps, air handling units, fans, chillers, generators and all other E&M equipment, making sure to include all relevant parameters for each piece of equipment. In addition, take hourly or daily readings according to the size of the equipment and variations in its operating parameters with time. For example, daily readings could be taken for pumps but hourly readings during equipment (e.g., chiller) start-up. Field readings should be entered on spreadsheets for further analysis.



CHAPTER 11 Data Centers and IT Equipment

OBJECTIVES

- Understand the linkages between data center efficiency and business profitability.
- Identify the major energy uses in data centers and the sources of energy inefficiency.
- Analyze and recommend initiatives to capture energy efficiency opportunities cost effectively.



OVERVIEW

For many companies, data centers are major contributors to total operating costs and environmental impact. Data centers typically have been designed and operated with little consideration for energy efficiency. As a result, there are many efficiency opportunities with exceptionally strong business cases, as discussed below.

Data centers are critical to business

Businesses of all types have become increasingly dependent on information technologies (IT). Most businesses rely on IT to manage core business functions, such as account management, web presence, and sales, as well as finances, human resources, and email systems. This trend is projected to persist as growth in IT requirements such as data processing and storage escalates.

IT computing equipment has evolved from mainframe machines used only for specialized functions to ubiquitous servers. Since critical business functions depend on computing capacity, 24-7 server availability, or "uptime," is important. To maximize uptime and capture economies of scale, servers are commonly aggregated into data center facilities, also known as "server farms."

Data center facilities are designed to supply high quality power to servers and keep equipment cool. Some large companies own their own data centers, while others outsource their IT functions or lease data center space managed by a hosting company. Data centers that lease space are known as co-location centers. It is also common for companies to set aside space in their office buildings for servers, commonly known as server closets.

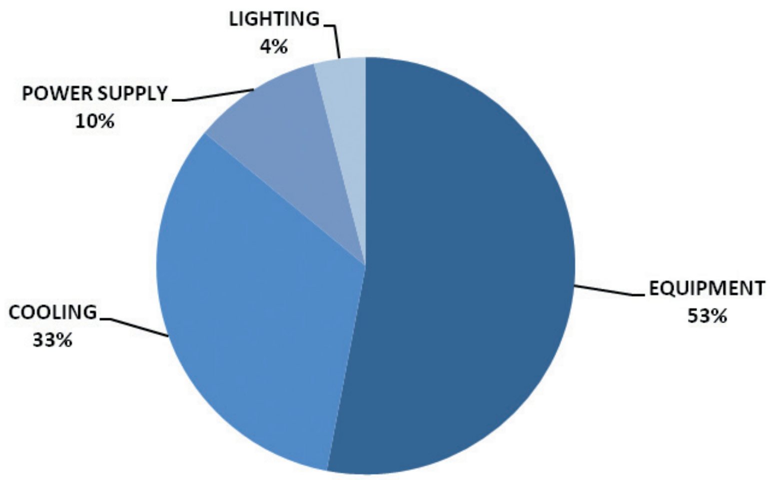
Data centers are heavy consumers of energy

Servers are major consumers of electricity. An individual server uses about 300 W of power, equivalent to three bright (100 W) incandescent light bulbs. Like an incandescent bulb, servers convert much of their energy to heat. However, since servers run constantly throughout the year, their energy use and heat production are much higher than any light bulb.

The energy consumption breakdown of a data center, illustrated in Figure 11.1, does not vary markedly from country to country considering that equipment characteristics are practically identical.

In many data centers, cooling systems and other infrastructure—power reliability equipment and lighting—use as much energy as the servers themselves. As a result, a single server with support systems has an annual footprint of more than five tons of carbon dioxide, the equivalent of a typical minivan driven 12,000 miles per year. Large data centers commonly house 10,000 or more servers. For many non-manufacturing companies, data centers are major contributors to corporate environmental footprint. Data centers have become significant power users in the United States. In 2006, the EPA estimated that 1.6% of electricity was consumed by data centers, a number projected to double by 2011. Even though Arab countries may not experience such an explosive growth, these projections nonetheless give a clear indication of the rising importance of IT in both public and private institutions.

FIGURE 11.1: ESTIMATED ENERGY CONSUMPTION BREAKDOWN OF AN AVERAGE DATA CENTER



A strong business case exists for making data centers more efficient

In a typical data center, less than 5% of the power consumed is used for computing operations. The other 95% is simply lost along the way—as heat in the servers, as conversion losses in power supplies, powering fans and lights, and in cooling systems required to remove all that waste heat.

Efficiency opportunities exist at each step of the system. In many cases, best practices are well known, as described below. Because increased energy use drives increases in both operating costs (electricity) and capital costs (for back-up generators, battery banks, and cooling systems), efficiency measures in data centers generally cut costs quite dramatically and pay back relatively quickly.

More specifically, efficiency measures provide economic value in three main ways:

- Saving energy reduces electricity costs required to power and cool servers.
- Energy efficiency increases the number of servers that can be supported by existing data center infrastructure, delaying or eliminating demand for expensive new data centers.
- In new data centers, designing more efficient systems can substantially reduce total capital outlays.

IT hardware and software efficiency measures may reduce server energy use by 90%. When coupled with the 40% efficiency potential of cooling system retrofits, an optimized data center system may reduce energy demand per computing operation by 92%.

Typically, data centers are designed for reliability, security, availability, and operating performance but seldom for energy efficiency. Consequently, energy efficiency measures should not jeopardize the operational readiness of IT equipment.

Costs and savings from efficiency measures vary among data centers. The savings and cost numbers in the rest of this chapter are rough estimates. They will need to be further tailored to specific data centers.

INFORMATION GATHERING GUIDE

Data centers are complex facilities, and efficiency potential depends on a wide range of factors. Data center decisions are subject to influence from many stakeholders—business executives, equipment purchasers, IT operators, and facilities managers. Expertise and knowledge about the topics below is spread across this diverse group. Participation from a team of stakeholders is needed to evaluate efficiency potential and implement efficiency programs.

These questions will help to start the dialogue on data center efficiency:

- Where are the servers located? (In server closets in offices; in company-owned data centers; or in leased data center space). Are IT services outsourced?

- What is the utilization of server capacity? Less than 5% indicates a large opportunity to increase hardware utilization; 20-30% is relatively good, but may still offer opportunities for improvement.
- What is the power density (W of IT equipment per area) of data center space? Less than 1.0 kW/m^2 indicates server densities are low. More servers could likely be added through retrofit programs.
- What is the data center power utilization effectiveness (PUE), defined as the ratio of total energy used by the data center to that actually consumed by servers over a particular time period? 1.5 is a reasonable target for retrofit efforts; industry average PUE is about 2.6. Microsoft has achieved a PUE of 1.2.
- What tier rating does the data centre have?
- Is there a scope for economizers and use of free cooling?
- Who (which department) pays for data center energy and operating costs?
- Who is responsible for IT strategy and data center investments?

TACTICS FOR REDUCING DATA CENTER ENERGY USE

There are five distinct categories that could all be applied simultaneously to achieve up to 90% energy use reduction by data centers.

A) MONITORING AND BENCHMARKING

Although monitoring and benchmarking do not directly create energy savings, these low-cost measures inform efficiency programs and track their impact.

A1) Calculate and monitor power utilization effectiveness (PUE). PUE is the ratio of total energy used by the data center to energy actually consumed by servers over a particular time period. An ideal data center would have a PUE of 1.0—all energy would be used to power servers. In reality, many data centers have a PUE of 2.0 or higher—the servers use just half of the energy. The rest is consumed by infrastructure systems to keep the data center environment cool and manage power quality. PUE can change over time and throughout the year depending on server loads and outside temperatures, so it should be monitored regularly to track data center performance.

A2) Track server utilization. Average servers operate at less than 10% of their potential capacity, due to unpredictable loading patterns. Installing software that monitors server use helps identify efficiency opportunities in underutilized servers as well as servers that are no longer being used at all.

A3) Install sensors to monitor temperature and humidity. Servers have specific temperature ranges (see Tactic E below). Improved monitoring can identify isolated “hot spots” within the data center where the air is significantly hotter than the average room temperature. This data can be used to focus cooling efficiency programs and allow more servers to be added to the data center without overheating.

A4) Use kW/ton metric to assess cooling system performance. The ratio of power consumed by a cooling system (kilowatts) to heat removed (tons equivalent to 12,000 BTU/hr) is a measure of the cooling efficiency. Optimized cooling systems may operate at 0.9 kW/ton or less. In many data centers, values are above 2.0 kW/ton, indicating a large potential for efficiency improvements.

ALTERNATIVE PERFORMANCE METRICS

PUE is the most widely used metric to compare data center efficiency to a baseline. However, two other metrics are increasingly being used:

• DCiE (Data center infrastructure efficiency): The inverse of PUE, DCiE is the ratio of server energy use to total facility energy use. It represents the fraction of energy consumption that is actually being used to power servers. An average value is 50%, but the best data centres may operate at nearly 90% efficiency.

• CADE (Corporate average data efficiency): CADE is a more advanced metric that considers the energy use by the server equipment as well as the facility efficiency. It is the product of facility energy efficiency, facility utilization, IT utilization, and IT energy efficiency. Since IT efficiency is difficult to quantify, the metric is still being developed. Nonetheless, it is helpful because it considers all of the relevant factors in data center efficiency.

B) ENERGY EFFICIENT SOFTWARE

The energy savings potential can be quite high for software measures, although the costs and expected savings of these measures will vary widely among companies.

B1) Design or purchase new software that minimizes energy use. Energy use is rarely an important constraint for software developers. As a result, software often puts high demands on server hardware. More efficient software can accomplish the same task with less energy. Software efficiency is a complex issue because efficiency measures are specific to individual programs and tasks. An important first step for software created in-house is to provide software designers incentives to write more energy efficient code. For purchased software, industry standards are still being developed to benchmark software energy performance.

B2) Implement power management software. Activating energy management programs can significantly reduce energy use. Like power save modes on desktop computers, servers can be programmed to go into idle mode when they are not being used.

C) IMPROVED SERVER UTILIZATION

"Server utilization" refers to the proportion of a server's processing capacity that is being used at any time. For most servers, energy use does not vary substantially based on the level of utilization. As a result, unused or underutilized servers use nearly as much energy as fully utilized servers. Significant efficiency gains can be accomplished by taking steps to reduce the number of servers running at low or zero utilization, and these steps can be taken at a comparatively low cost.

C1) Unplug and remove servers that are not being used at all. Surprisingly, a significant fraction of servers (in some cases, 10%) in many data centers are no longer being used. If an office employee quits, others would quickly notice if the unused desktop computer kept turning on every day. Servers are less obvious; they can run their operating systems and background applications invisibly for months or years before they are removed. To identify unused servers, run programs to monitor network activity over time. This effort will identify potential "zombie servers," which then must be individually investigated to determine whether they can safely be unplugged and removed. The cost of unplugging and removing unused servers is relatively low with a relatively low payback period not exceeding 1-2 years.

C2) Virtualize multiple servers onto single machines. New technologies have been developed in the last five years that allow multiple operating system copies to run simultaneously on a single server. This process is known as virtualization. Virtualization offers large energy savings potential, because it consolidates several servers onto a single, more utilized server. Virtualization presents challenges because entire operating systems must be transferred from one server to another. However, the potential benefits are so great that many companies are now rushing to implement virtualization initiatives. Virtualization potential is often quantified as 3:1 or 5:1, reflecting the number of servers that can be consolidated onto a single machine. In many cases, however, virtualization levels exceeding 20:1 are possible. The savings achieved could be quite substantial, reaching 75% of IT equipment energy consumption with a payback period not exceeding 2 years.

C3) Consider advanced resource allocation through application rationalization and cloud computing. In addition to virtualization, new techniques are available that allow computing demands to be allocated to any server with capacity, without compromising security. Called cloud computing, these programs distribute loads among servers to optimize utilization levels. Unneeded servers may be shut down to conserve power until they are required to handle spikes in load. In addition, applications rationalization measures may be implemented on a single server to allow multiple copies of an application to run simultaneously. In this way, one or more servers may be consolidated onto a single machine.

D) ENERGY EFFICIENT SERVER HARDWARE DESIGN

Buying efficient hardware is a cost effective way to capture major energy savings. Although efficient hardware sometimes costs more upfront, when the lifecycle cost of ownership is considered, the energy savings over time more than pay back the extra cost. Since most servers are replaced (refreshed) every three to four years, frequent opportunities exist to upgrade to more efficient equipment. The measures described below involve low expenditures with an estimated payback period of less than 1 year.

D1) Purchase best-in-efficiency-class (BIEC) servers. For a given level of performance (processing speed, RAM, etc.), servers on the market exhibit a wide range of energy demand. In other words, performance is only slightly correlated to energy. Despite this, most companies' purchasing decisions do not consider energy efficiency. Working with IT and supply chain departments to prioritize energy efficient server models during normal refresh cycles has the potential to save up to 50% of server energy. And since efficient servers are not necessarily costlier, this is a low-cost opportunity.

D2) Eliminate unnecessary components and use efficient power supplies, fans, and hardware when building customized new servers. Some companies custom design the servers used in their data centers. This opens the door to a variety of efficiency measures that save capital costs and energy. The first step is to eliminate unneeded components that come standard in many servers. Items such as disk drives and graphics cards may be unnecessary depending on the server's function. Next, efficiency of specific components should be considered as part of the purchasing decision. Power supplies, fans, chips, and storage drives offer potential efficiency gains. To realize these opportunities, analyze how decisions are made for server components and ensure that energy use is a metric.

D3) Mandate efficient power supplies. In recent years, efforts to raise power supply efficiencies have gained momentum. Server power supplies transform electricity to the low voltages demanded by electronic components. Historically, many power supplies have operated at as low as 60% efficiency—up to 40% of energy consumed by the server is lost as heat immediately. Many off-the-shelf servers today have power supplies certified by the 80 PLUS program, which demands at least 80% average efficiency. In fact, power supplies with efficiencies of 90% are available (the 80 PLUS program and the Climate Savers Computing Initiative provide lists of manufacturers offering high efficiency power supplies).

BUILDING AN ULTRA-EFFICIENT NEW DATA CENTER

This chapter deals primarily with existing data centers. However, when a new data center is built, an even wider suite of efficiency measures should be considered. In addition to the IT hardware and software measures discussed in this section, innovative strategies for cooling and power supply may be adopted. For example:

- Air side economizer. Design the data center to directly use outside air for cooling when the temperature is low enough. This is similar to opening the window of a house to cool a room rather than using an air conditioner.
- Remove server fans. If a centralized fan system is used to pressurize the cold aisles, it may be possible to remove the inefficient fans in each server.

- Direct liquid cooling. Pipe coolant directly to the IT hardware; liquid is a much more effective remover of heat than air.
- Dynamic UPS. Instead of a large battery bank to provide uninterruptible power, use a rotating flywheel system.

These strategies can reduce PUE to below 1.2, enabling major operating cost savings at little or no additional capital cost.

D4) Use power management equipment to shut down servers. Many servers are not used for significant periods of the day. Often, unused machines remain on, even when their loads are predictable. Power management applications and hardware (smart "power distribution units") can be programmed to shut servers down and then bring them back online when needed. Since most servers use more than half of their total energy consumption when idle, power management measures have the potential to significantly reduce server energy use.

TABLE 11.1: SERVER HARDWARE EFFICIENCY COSTS AND BENEFITS

	IT energy savings (%)	Cost per server ($)	Payback (years)
Purchase BIEC	40%	$0-100	<1
Optimize custom builds	Varies	Varies	-
Power supplies	20%	$0-100	<1
Advanced allocation	Varies	Varies	-

E) COOLING SYSTEM OPTIMIZATION

Cooling systems account for less than half of data center energy use, but there are often large efficiency opportunities that can be implemented with very reasonable payback periods.

E1) Block holes in raised flooring. Many data centers use an open plenum beneath a raised floor to distribute air to the server racks. Fans are used to pressurize the air in the plenum. Perforated tiles are positioned where cold air is needed (at the air intake side of server racks), which allow cold air to be pushed up into the room. However, in many data centers, floor tiles are removed to run wires or conduct maintenance and never replaced. This allows cold air to escape and reduces the efficiency of the cooling system. An easy fix is to cut out small holes for cables and replace floor tiles to cover holes. It is also possible to use other approved floor cover materials as inexpensive options.

E2) Bundle underfloor cables. In many data centers, airflow is restricted in the plenum by tangles of wires and cables. Organizing underfloor cables can reduce fan energy use and improve cooling effectiveness, allowing more servers to be added to the data center.

E3) Relax artificially-set temperature and humidity constraints. Allowable temperatures in data centers are typically restricted to narrow ranges in order to reduce risk of server failure. Many data centers adopt the "recommended range" from American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) of between 18 and 27ºC (64˚ and 80˚F). However, server manufacturers guarantee that their servers will operate reliably in significantly warmer temperatures. For example, a typical Sun server specifies 35ºC (95˚F) as the upper limit temperature. Allowing warmer data center temperatures reduces cooling energy use and allows more servers to be added to the data center. For this measure, implementation is simple—raising temperature setpoints requires only a modification of controls. The reluctance of IT systems operators to approve this measure is the primary barrier to adoption.

E4) Enclose "hot" or "cold" aisles and block holes in racks with blanking panels. To maximize efficiency of an air-cooled data center, cold supply air should be physically isolated from hot return air. The simplest way to achieve this is to encapsulate an aisle of server racks by adding end doors, roof panels over the racks, and "blanking panels," which fit into the racks and block air from flowing through empty slots. When implemented, air flows from the cold aisle through the servers to the hot aisle and exhaust air stream without "short-circuiting" (cold air bypassing servers and merging with hot exhaust air) or "recirculation" (hot air flowing back to the server inlets, leading to overheating problems). Implementing aisle containment measures can disrupt data center operations if racks need to be repositioned, but can enable up to 25% cooling energy savings.

TABLE 11.2: COOLING SYSTEM EFFICIENCY COSTS AND BENEFITS

	Cooling energy savings (%)	Cost per server ($)	Payback (years)
Block holes	Up to 5%	$5	1
Bundle cables	2%	$1-5	<1
Relax temperature constraints	Varies	$0	Varies
Aisle containment	Up to 25%	$40	2
Facility audit	Varies	Varies	Varies

E5) Commission a facility energy audit: Mechanical engineering auditors evaluate HVAC systems and operations. After spending a day on-site, they can estimate energy savings and cost impacts of efficiency opportunities. In addition to the cooling system measures described above, they may recommend retrofits to use outside air for cooling, optimize condenser water and chilled water temperature setpoints, and other retrofit measures.

F) OTHER LOADS: POWER SUPPLY AND LIGHTING SYSTEMS

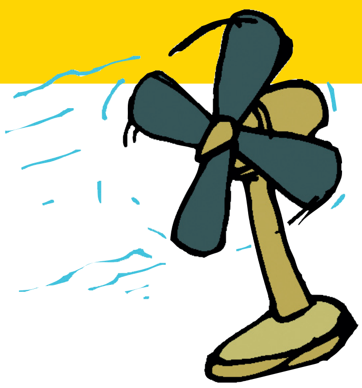
Power supply and lighting should not be overlooked in the search for energy efficiency opportunities in data centers. Combined, they make up about 15% of electrical energy consumption.

F1) Optimize power supply and conversion systems to maximize efficiency. The uninterruptible power supply (UPS) typically uses a battery bank to ensure that no blips in power input result in server failure. However, the process of switching between voltages and alternating to direct current is only 85% efficient. Since all energy used by servers passes through the UPS system, 15% of all energy is lost. One way to improve UPS efficiency is to install a "Delta Conversion" system, which diverts most AC power flows around the AC/DC conversion and battery equipment, greatly reducing conversion losses.

F2) Reduce lighting energy use with automated controls and more efficient fixtures. Lights are a small piece of data center energy use, but they can easily be improved. In many data centers, lights are glaringly bright, so that workers can see into the dark racks to configure servers. Furthermore, lights are often on 24-7, since a worker exiting a large data hall never knows if someone else is still at work. Occupancy sensors allow lights to turn off when the data center is empty, potentially saving 50% or more of the lighting energy. Lights can also be divided into separate banks, so that the entire space does not have to be lit when people are working in one area. Finally, the quality of light may be improved by using light colored interior surfaces and server racks and by using indirect lighting fixtures.

Additional information

Further information is available at:
www.searchdatacenter.bitpipe.com/
www.plugloadsolutions.com/About.aspx
www.climatesaverscomputing.org/



In a nutshell …

Tactics for reducing data center energy use

1. Prerequisite: Monitoring and benchmarking

- Calculate and monitor power utilization effectiveness (PUE).
- Track server utilization.
- Install sensors to monitor temperature and humidity.
- Use kW/ton metric to assess cooling system performance.

2. Energy efficient software

- Design and purchase new software that minimizes energy use.
- Implement power management sotware.

3. Improved server utilization

- Unplug and remove servers that aren't being used at all.
- Virtualize multiple servers onto single machines.
- Consider advanced resource allocation through applications rationalization and cloud computing.

4. Efficient server hardware design

- Purchase best-in-efficiency-class (BIEC) servers.
- When custom-building new servers, eliminate unnecessary components and use efficient power supplies, fans and hardware.
- Mandate efficient power supplies.
- Use power management equipment to shut down servers.

5. Cooling system optimization

- Block holes in raised floor.
- Bundle underfloor cables.
- Relax temperature and humidity constraints.
- Enclose "hot" or "cold" aisles and block holes in racks with blanking panels.
- Commission a facility audit.

6. Other loads: Power supply and lighting systems

- Optimize power supply and conversion systems to maximize efficiency.
- Reduce lighting energy use with automated controls and more efficient fixtures.

CHAPTER 12 Company Vehicles

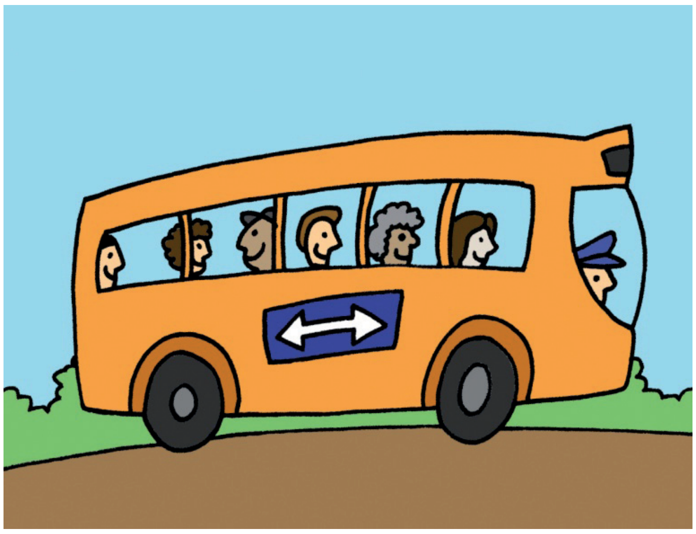
OBJECTIVES

- Identify opportunities to reduce fuel consumption and car emissions by corporate fleets without sacrificing performance or functionality.

- Set criteria for selecting company-owned or company-leased vehicles for executives and employees.

OVERVIEW

Additional cost-effective energy efficiency gains can be made in company vehicle fleets. Operating a cleaner, greener fleet means more than just counting the number of hybrids or alternative fuel vehicles on the road. Successful management means actively measuring and reducing greenhouse gas (GHG) emissions. Many low-to-no-cost strategies are available to cut fuel consumption and emissions from corporate fleets. These include right-sizing vehicles and engines, reducing idling, reducing kilometers traveled through improved routing, and reducing vehicle curb weight. To get the largest quantity of reductions, look first at the vehicles that comprise the largest segment of the fleet. A 3% efficiency improvement in 100 vehicles is usually more impactful than a 100% improvement in three vehicles.



INFORMATION GATHERING GUIDE

- What are the main functions served by the fleet (i.e., delivering beverages, transporting sales staff, storing tools for technicians)?
- How many and what types of vehicles does the company use?

- What is the average mileage driven per function?
- Are there more fuel-efficient vehicles that could do the job?
- What processes are in place for tracking fuel consumption?
- What efforts have been made to educate drivers about fuel efficiency?
- Are fleet emissions calculated at least annually?
- Is there currently an environmental program for the fleet? What are the goals?
- Does the company self-manage the fleet or does it work with a fleet management company?

TACTICS FOR REDUCING VEHICLE ENERGY USE

A) IMPROVE VEHICLE SELECTION

The most important environmental decision for a fleet is which vehicles to source. Relatively minor changes in vehicle selection can result in significant environmental—and financial— benefits over time. Consider the following strategies for improving vehicle selection:

A1) Select the right size. Analyze the operational needs of the fleet and eliminate excess vehicles. Match the duty requirements with the appropriate class and size vehicles. Special features, such as 4-wheel drive and 6- or 8-cylinder engines can increase costs and emissions.

A2) Choose "best-in-class" Select vehicles with the highest fuel efficiency in their class that meets your organization's price and performance needs. Table 12.2 indicates fuel economy performance of different vehicle models. Refer to the table as a guide when selecting vehicles.

A3) Evaluate total lifecycle costs. Make vehicle selections based on costs over the full life of the vehicle, including acquisition, fuel consumption, depreciation, and resale.

A4) Use incentives. Consider offering employees popular options such as interior upgrades, sunroofs, and satellite radios as incentives to select more cost-effective, efficient vehicles.

B) IMPROVE VEHICLE USE

The way a vehicle is driven and maintained affects operating cost, fuel economy, and greenhouse gas emissions. A few actions in this area can yield significant savings:

B1) Educate drivers. Teach drivers how to be more efficient on the road and drive fewer miles. Aggressive driving behavior such as speeding, coupled with rapid acceleration and deceleration, for instance, often extracts a high fuel penalty: up to 40%. Idling is another inefficient practice—ten seconds of idling uses more fuel than re-starting the engine.

A key to maximizing your vehicle's fuel economy and limiting its global warming emissions is to drive sensibly. You can do so by:

- Adhering to speed limits: Most vehicles reach their optimal fuel economy below 100 kilometers per hour. Above this speed, fuel economy can decrease quickly. According to some estimates, every eight k/hr increase above 104.5 k/hr decreases your vehicle's fuel economy by 7%.
- Accelerating gradually: Higher RPM driving uses more fuel than lower RPM driving. By accelerating gradually, you can keep your vehicle's RPMs lower and maximize fuel efficiency.
- Anticipating stops: By actively monitoring the traffic ahead, you will notice coming slow downs or stops well in advance. When you see a need to stop up ahead, coast. Don't continue to accelerate and then brake at the last minute. Such action wastes fuel by converting energy from motion to friction heat.
- Reducing idling: An idling vehicle wastes fuel and increases greenhouse gas emissions. So, turn off the engine if you are not in traffic and are going to be stopped.

B2) Improve maintenance. Ramp up the vehicle maintenance program. In order for vehicles to perform at their best and maintain maximum resale values, they must be well maintained. Allowing a vehicle to fall out of shape can have significant impacts on fuel consumption and operating costs. Regular oil changes, proper tire inflation, and other preventive maintenance practices increase fuel efficiency. Table 12.1 presents a few examples.

TABLE 12.1: POTENTIAL FOR INCREASED FUEL ECONOMY THROUGH IMPROVED MAINTENANCE

Vehicle condition	Potential increase in fuel economy from correction of problem
Under inflated tires	3-4%
Wheels out of alignment	4%
Malfunctioning oxygen sensor	40%
Improper weight of motor oil	2%

B3) Employ other efficient driving techniques. By avoiding aggressive driving behaviors, minimizing idling, planning ahead and keeping up on maintenance, you will be on your way to maximizing your vehicle's fuel economy. Here are a few more ways to save:

- Consider cruise control: On flat highways, cruise control helps to maintain a steady pace, which maximizes fuel economy. In hilly areas however, it can cause rapid acceleration, which harms fuel economy.
- Use overdrive: Vehicles consume less gas at lower RPMs. Using overdrive with automatic transmissions will cut back on fuel consumption when you are operating at a steady speed, such as on the

highway. If you are driving a manual transmission, consider shifting sooner.

B4) Prepare before you go. There are several ways you can reduce fuel consumption before you even get in your car.

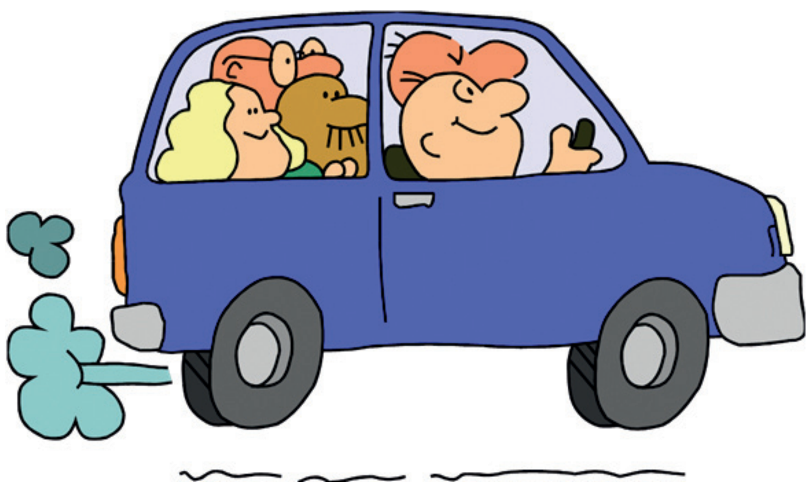
- Plan, plan, plan: The best way to reduce fuel consumption is to minimize the distance traveled on the road. By optimizing routes, you will reduce fuel consumption and decrease the time spent behind the wheel. Before you head out on your way, ask yourself:

i. Do I now how to get where I want to go?
ii. Am I taking the most efficient route?
iii. Can I combine another necessary stop into this trip and avoid a future trip?
iv. Should I make this trip at a time when traffic will be lighter?

- Dump excessive cargo weight: Lugging around an extra 100 pounds of cargo weight can reduce fuel economy by 2%. Before you head out on your next trip, check the trunk and remove unnecessary items.

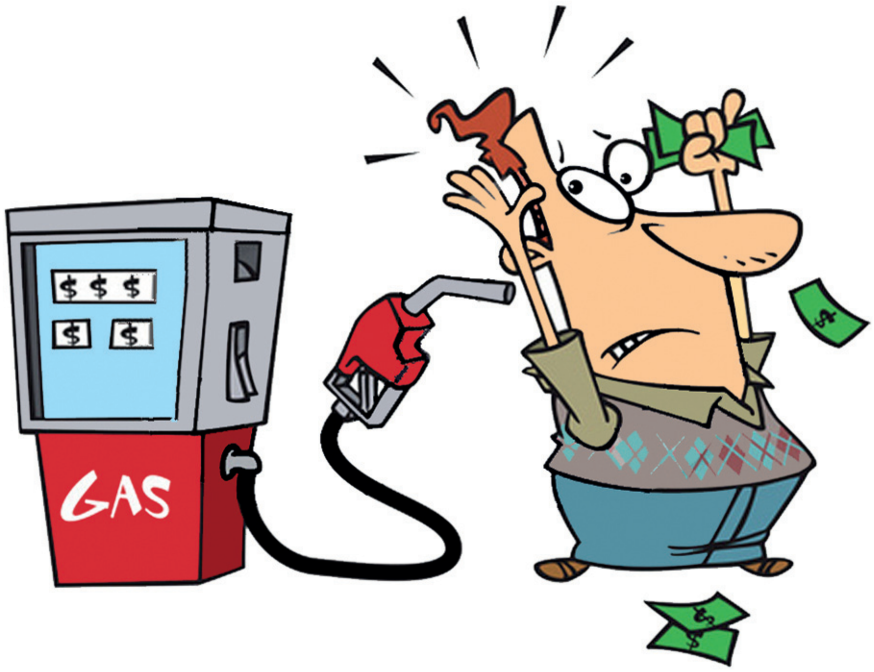
- Remove items that interfere with aerodynamics: Roof racks and other accessories that interfere with aerodynamics can cause up to a 5% decrease in fuel economy.

B5) Incorporate technology. Take advantage of new technologies, such as routing software, GPS systems, and fuel management software to maximize efficiency. Telematics products allow for real time monitoring and data collection, which can increase safety, reduce idling, cut fuel consumption, and decrease emissions.



C) FUEL ECONOMY PERFORMANCE BY CATEGORY

Due to stricter regulations in many parts of the world to limit CO_2 emissions from the transport sector, combined with higher prices of fuel and increasing awareness among consumers, car manufacturers have moved into developing more efficient engines. This is not limited to hybrid or electrical engines alone, but also to conventional engines which underwent major improvements, and led, in some cases, to achieve reduction of emissions by up to half, while keeping the same power. Cleaner public transport and town planning and zoning solutions which limit the use of cars remain the main elements for a major shift in the sector.



As personal transport will still be needed, there are elements to be considered in making the right choice. First, a car should be chosen based on the real use envisaged, which will determine the category to select from. Second, within each category there are many choices, based on consumption and emissions. The lists compiled in this Handbook are meant only to give an idea for comparison, and to help make the optimal choice. Fleet managers and individuals should always ask for detailed information on fuel consumption and CO_2 emissions.

Popular websites currently have updated information on vehicle mileages and equivalent CO_2 emissions, such as the 'car-fuel-data' web portal (http://carfueldata.direct.gov.uk/), which includes all cars currently being traded in the UK, and other websites more tailored to specific 'green' buyers, such as *http://www.nextgreencar.com/* 'Next-green-car', in its own words, provides expert and independent information to consumers researching more environmentally friendly cars. All the vehicles' models and types within each model, are listed and labeled or scored from 100 (most polluting) to 0 (greenest), with information on their carbon dioxide emission content and fuel usage. However, some models sold in the Middle East markets, especially those with 8 cylinders, might not be found on such sites, as they are specifically made with larger engines and higher consumption to cater for public demand in the unregulated Arab countries. Moreover, many models in the lists are available in hybrid versions in other markets, but are not sold by dealers in the Middle East, due to lack of regulations and incentives. Few hybrid cars which are sold on limited scale in the region have been included in the list.

Most car dealers in the Arab countries do not provide data on fuel economy and carbon dioxide emissions, neither on their websites nor in the brochures distributed in the Middle East. Fleet managers and consumers should refuse to purchase a car if this information is not provided. Rules should be enacted in all countries to make providing data on fuel consumption and CO_2 emissions mandatory for every model sold. Tax exemptions should be applied to encourage the use of lower consumption/lower emission cars, while applying higher taxes commensurate with higher consumption/emissions. Companies, the public sector buyers and consumers in general can start in the right direction by setting a limit for emissions allowed for cars purchased from each category.

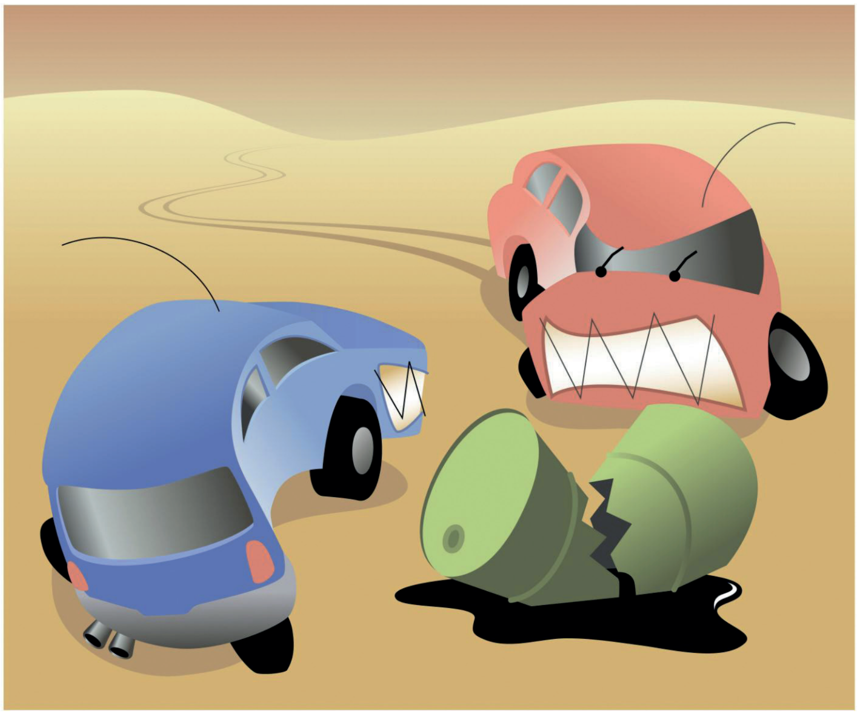


TABLE 12.2: FUEL ECONOMY PERFORMANCE OF DIFFERENT VEHICLE MODELS

CATEGORY 1: COMPACT CARS (UP TO 1.4 LITERS)

Car	Engine capacity (liters)	CO_2 emissions (g/km)	Combined fuel consumption (l/100km)
Citroen C1 Compact	1	106	4.6
Nissan Micra	1.2	115	5
Fiat 500	1.2	119	4.2
Chevrolet Spark	1	119	5.1
Toyota Yaris	1.3	123	5.4
Audi A1	1.4	124	5.3
Volkswagen Polo	1.2	128	5.5
Honda Jazz	1.3	128	5.5
Hyundai i10	1.2	129	5.5
Suzuki Swift	1.2	129	5.6
Opel Corsa	1.4	138	5.9
Ford Fiesta	1.4	154	6.5

CATEGORY 2: MEDIUM -SMALL CARS (UP TO 1.6 LITERS)

Car	Engine capacity (liters)	CO_2 emissions (g/km)	Combined fuel consumption (l/100km)
Chevrolet Aveo	1.2	130	5.4
Citroen C2	1.4	130	5.6
Hyundai Elantra	1.6	138	7.4
Volkswagen Golf	1.4	144	6.2
Audi A3	1.8	152	6.6
Renault Clio	1.6	155	6.7
Peugeot207	1.6	160	6.9
Opel Astra	1.6	167	7.1
Mazda 3	1.6	167	7.6

CATEGORY 3: MEDIUM - FAMILY CARS (UP TO 2.5 LITERS)

Car	Engine capacity (liters)	CO_2 emissions (g/km)	Combined fuel consumption (l/100km)
Toyota Prius *(hybrid)*	1.8	92	4
Chevrolet Cruze	1.8	155	6.6
BMW3 Series	2	159	6.8
Citroen C4	1.6	159	6.9
Volkswagen Passat	1.8	165	7.1
Honda Civic	1.8	١٦٥	٧,١
Mercedes C 180	1.6	172	7.4
Mazda 6	2	176	7.6
Renault Ménage	2	178	7.7
Hyundai Sonata	2.4	179	8.7
Nissan Qashqai	2	179	7.6

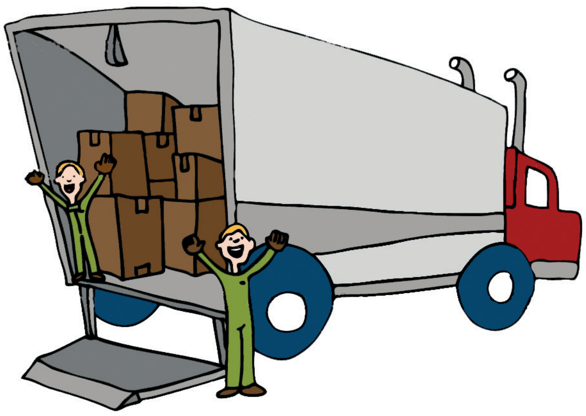
Ford Mondeo	2	179	7.7
Honda CR-V	2	193	8.4
Audi A4	2	194	8.3
Lexus IS250	2.5	194	8.4
Opel Insignia	2	198	8.4
Subaru Legacy AWD	2.5	220	8.2
Nissan Altima	2.4	220	9.2
Renault Espace	2	223	9.4
Toyota Camry	2.4	233	10.2

CATEGORY 4: EXECUTIVE CARS (UP TO 3.5 LITERS)			
Car	Engine capacity (liters)	CO_2 emissions (g/km)	Combined fuel consumption (l/100km)
Lexus RX450 hybrid	3.5	145	6.3
Honda Accord	2	170	7.3
BMW 523i	3	178	7.6
Lexus GS450 hybrid	3.5	179	7.7
Mercedes E350 Blue Efficiency	3.5	205	8.8
Peugeot 407	2	207	8.7
Audi A8	4.2	219	9.5
BMW 740i	3	232	10.1
Nissan Murano	3.5	248	10.6
Jaguar XF	3	249	10.7
Cadillac CTS	2.8	263	9.5

The tables, compiled by AFED, list a selection of vehicles available in the Middle East markets, according to engine size, body size and CO_2 emissions. All cars included are 2011 model-year, run on petrol and have automatic transmission and air-conditioning, conforming to the majority of cars sold in the region. Engines only up to 3.5 liters were included. Data have been collected from manufacturers and other independent sources. CO_2 emissions are in gram per 1 kilometer, combined (average) consumption is in liters per 100 kilometers. **Note that there might be overlap among categories, especially between Medium-Family and Executive.**

Additional information

Further information is available at:
http://www.fueleconomy.gov/feg/maintain.shtml
http://www.buzzle.com/articles/what-affects-gas-mileage-7tips-on-improving-fuel-efficiency.html
http://www.environment.gov.au/settlements/transport/fuelguide/tips.html



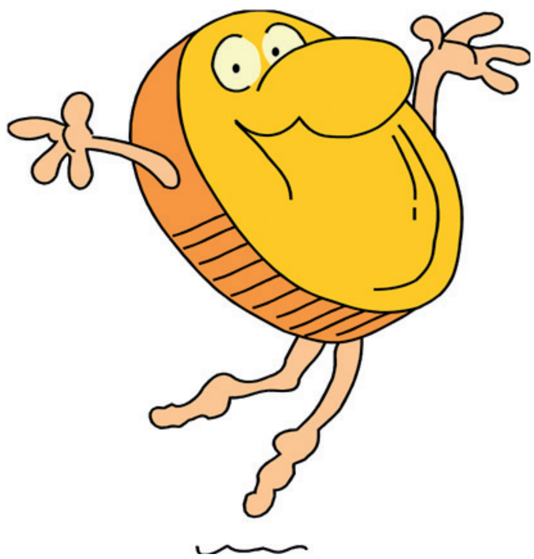
CHAPTER 13 Energy Efficiency Finance

OBJECTIVES

- Develop a financial analysis method that reflects the company's investment analysis framework.
- Develop a plan recommending which energy efficiency investments should be made and how they can be either paid for out of existing department budgets, budgeted for next year, or financed through other means.

OVERVIEW

Each potential energy efficiency project will require a forecast of the initial incremental investment, annual savings, and costs. Energy cost savings will likely be the main financial driver, but changes in labor and replacement costs of equipment may also be significant. The economic feasibility of investments are often evaluated using net present value analysis, the payback period, the internal rate of return, or by consideration a combination of all three.



Financial analysis requires the calculation of the **net present value (NPV),** the sum of forecasted discounted cash flows minus the initial investment, as the primary measure of a project's attractiveness. Using NPV properly positions energy savings opportunities as an investment, not as an expense. The discount rate is one important variable that affects the calculation of NPV.

Discount rate: As a default, the **discount rate** in financial analysis should be set as the host company's internal **hurdle rate**. Discount rates reflect both the time value of money and the risk involved in a specific project. Typically, energy efficiency investments have much lower risk than other investments that companies choose to pursue. From a strictly financial perspective, efficiency investments should therefore be evaluated using correspondingly lower discount rates. However, most chief financial officers (CFO) will not want to adjust discount rates for relatively small investments because of the time and discussion entailed in settling on the "right" number. If a large energy-efficient investment, such as a new **HVAC** system, is on the threshold of profitability, then it may be worth presenting a sensitivity analysis using multiple discount rates.

Payback is the time required for accumulated savings to equal the initial investment. This metric is frequently used in energy efficiency investments. It is simple to understand and can be powerful when the payback period is one to three years. In most variants, however, paybacks ignore cash flows after the payback period and the time value of money, thus underestimating the value of a longer-term investment.

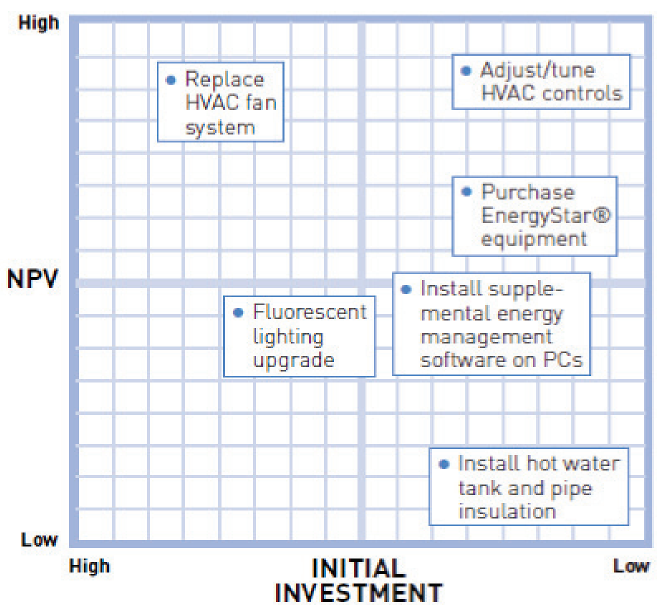
Again, if this metric is used, it should be accompanied by an NPV calculation.

The internal rate of return (IRR) is closely related to NPV and is used by corporations with similar frequency. If IRR is used as the principle criterion, however, it could sway the corporation towards efficiency improvements that require little to no upfront investment, even if these generate less financial value (and energy savings) to the firm. On a more positive note, the relatively simple cash flow structure of most energy efficiency projects prevents some of the common calculation errors that plague this metric.

Prioritizing efficiency investments

From a financial perspective, the most attractive investments will be those that generate the greatest cash flow in excess of the cost of capital—those with the largest NPV. Recognizing that the size of the upfront investment does have an impact on the decision, a prioritization matrix can serve as a helpful visual tool to organize information about NPV and initial investments, as illustrated in Figure 13.1. Investments with relatively low initial investments and high NPV or energy savings potential should obviously be pursued first.

FIG. 13.1: EXAMPLE PRIORITIZATION MATRIX FOR POTENTIAL ENERGY EFFICIENCY INVESTMENTS



Financing investments

Once investments are prioritized, the next challenge is to determine how they will be paid for. There are four broad categories of payment structures, including cash, loan, leasing, or performance contracts.

Cash: Paying with cash is ideal if the investment is relatively small and the firm has a strong balance sheet. It also allows the firm to depreciate the investment. If the firm does decide to pay in cash, no adjustments need to be made to the base NPV analysis.

Loan: Depending on the cash position of the host company and the size of the required investments, a loan may be required. It may be useful to identify whether there are any below market rates available for specific investments. In Lebanon for example, the Central Bank of Lebanon launched the "National Energy Efficiency and Renewable Energy Account" with the Lebanese Center for Energy Conservation, whereby 0% interest loans are available for renewable energy and energy efficiency projects.

Performance contracts: This method of financing shifts some or all of the risk to an outside vendor and can be applied to purchases and leases. In this structure, a service provider pays the up-front costs of an efficiency upgrade and receives the resulting savings from reduced energy costs. Alternatively, the service provider pays a percentage of the up-front costs in exchange for a percentage of the resulting savings. Any performance contract should be valued against the cash flows from the purchase option and should consider staff time required to negotiate the contract and manage the project implementation and maintenance.

INFORMATION GATHERING GUIDE

The CFO or controller should be able to provide information on the company's budgeting process and investment criteria.

- How does the host company evaluate internal facilities or fleet investments?
- Can the host company provide an analysis or presentation for a recent, successful investment?
- What discount rate does the host company typically use? How was this discount rate determined?
- Are the following items depreciated? On what schedule?
  - ✓ Lighting equipment
  - ✓ Computers and office equipment
  - ✓ HVAC systems
- When are budgets determined for each department? Is there flexibility in this process or is it fixed?
- When does the host company choose leases over purchasing assets?
- What types of services does the host company outsource?

CHAPTER 14 Non-Financial Considerations

OBJECTIVES

- Understand the written and unwritten "rules of the game" at the host company.
- Develop non-financial arguments for energy efficiency investments relevant to the host company.

OVERVIEW

Each company has a different set of policies, personalities and decision-making processes. Some of these are formalized in writing, others are cultural and unwritten. The more these elements are understood, the higher the likelihood a successful case for energy efficiency investments can be made. Unwritten company policies and processes can usually be learned through careful observation during meetings as well as by having candid conversations with trusted contacts.

There are a number of powerful arguments for making improvements to office space that have nothing to do with finance. It is frequently noted by people in the field that "no one asks for the payback period of carpet." Non-financial arguments must connect with the host company's goals and values and appeal to the emotions of the decision maker. Some of these arguments may include:

- Higher quality office environment (better lighting, air quality).
- Higher worker productivity and morale.
- Reduced absenteeism.
- Easier to recruit and retain skilled labor.
- Meeting or anticipating regulatory requirements.
- Adopting industry best practices.
- Public relations.
- Demonstration of leadership on environmental stewardship.

Even with an airtight business case, energy efficiency investments may not take place. In Chapter 4, several barriers to investments were discussed. One needs to address the organizational issues of scarce resources, language barriers, coordination challenges, and accountability. In essence, who are the people responsible for the actual work and do they have the motivation and resources to accomplish it?

INFORMATION GATHERING GUIDE

- What are the host company's general corporate goals?
- How is the host company run? Is the company an autocracy, bureaucracy, or technocracy?
- What behaviors does the host company value?
- Obtain a copy of the organizational chart—understand who is responsible for what.
- For each type of investment:
  - ✓ Who needs to approve it?
  - ✓ Who can say no?
  - ✓ Who benefits?
  - ✓ Who is responsible for implementation?
  - ✓ What motivates this person?
- What is the process for getting new investments approved?
- Talk to other people in the office who were successful in getting things approved.
- Are there upcoming meetings where energy efficiency issues can be brought up and discussed?
- Are employees satisfied with current lighting and office temperature maintenance?
- What energy efficiency investments have industry peers made?
- Has anyone at the host company championed energy efficiency initiatives recently?
- Of those who have demonstrated interest in energy efficiency, who is in a leadership position in the host company?
- How might energy efficiency investments help meet other corporate goals?

APPENDIX A Lighting background information

Lighting functions

It is important to assess the function for which lighting is needed when considering options for efficiency improvements. Lighting functions include:

- Ambient lighting provides general illumination indoors for daily activities, and outdoors for safety and security.
- Task lighting facilitates particular tasks that require more light than is needed for general illumination, for example, desk lamps.
- Accent lighting draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment, such as lights in lobbies and conference rooms.

Matching the amount and quality of lighting to the needed function is a key strategy to improving overall lighting environment and efficiency in any space. For example, using task lighting to reduce ambient lighting may not only reduce energy demand, but will also allow for greater flexibility and higher quality working conditions.

Light sources

Within the lighting industry, electric light sources are referred to as lamps, which include bulbs and tubes. Common light sources include:

- Incandescent: Incandescent lamps are one of the oldest electric lighting technologies available. Incandescent bulbs produce light by passing a current through a filament, causing it to become hot and glow (also releasing waste heat).

- Tungsten halogen: Tungsten halogen lamps are slightly more energy efficient and last longer than standard incandescents. One advantage of the tungsten halogen lamp is its controlled beam spread, which makes it ideal for accent lighting. Tungsten halogen lamps can be used in track, recessed, outdoor spot, and floodlight settings.

- Fluorescent:

✓ Fluorescent tube lamps: Fluorescent tube lamps are very commonly used in business applications; these lamps are generally identified as T12 and T8, referring to the diameter of the tube. T12s are 38.1 mm in diameter, while T8s are 25.4 mm. Typically, T8s are more efficient than T12s.

- ✓ Compact Fluorescent Lamps (CFL): CFLs have higher efficacy and longer life than comparable incandescent lamps. CFLs come in a variety of shapes and sizes and are compatible with most fixtures designed for incandescent bulbs.

- Light emitting diodes (LED): LEDs are a solid-state light source that delivers a direct beam of light at a very low wattage. LEDs currently have efficiencies comparable to that of compact fluorescent lamps, between 20-60 lumens per watt. Over the next twenty years, however, technology is projected to be able to achieve more than 150 lumens per watt. Although the efficiency of the individual LEDs currently may not be significantly higher than other conventional sources, the efficiency of the entire lamp and luminaire combination is very high, as nearly all of the light gets directed out of the luminaire.

- High-intensity discharge (HID): HID bulbs have a longer life and provide more light per watt than any other light source. HID bulbs are commonly used for outdoor security and landscape lighting. Mercury vapor lamps, which originally produced a bluish-green light, were the first commercially available HID lamps. Today, they are also available in a color-corrected, whiter light. Increasingly, the more efficient high-pressure sodium and metal halide lamps are replacing mercury vapor lamps. Standard high-pressure sodium lamps have the highest efficacy of all HID lamps, but they produce a yellowish light. High-pressure sodium lamps that produce a whiter light are now available, but their efficiency is somewhat lower than traditional high-pressure sodium lamps. Metal halide lamps are less efficient but produce an even whiter, more natural light. Colored metal halide lamps are also available.

Guidelines for lighting design

Seven steps should be considered when designing or renovating a lighting system. These steps are:

1. Improve the visual quality of the task. Identify specific visual tasks and recommend appropriate illumination, including task lighting.
2. Improve geometry of space, cavity reflectance. Use light and color of the room to increase the use of natural light; rearrange furniture for optimal lighting.
3. Improve lighting quality. Cut veiling reflections through more indirect light distribution and reduce glare.
4. Optimize lighting quantity. Balance levels of ambient and task lighting and ensure adequate light levels for tasks being performed.
5. Harvest/distribute natural light. Daylight improves the visual environment and results in increased productivity and energy savings. It is important to shade windows to prevent glare and heat gain and control the amount of daylight entering the building. Daylight can be

redirected to where it is needed and be integrated with electric lights.

6. Optimize technical equipment. Lamps, ballasts, reflectors, and other technology must be optimized for maximum performance.
7. Control, maintain, and train. Proper maintenance of equipment is a crucial component to keeping technology in the best shape it can be.

Additional information

For additional information on lighting design optimization, see:

Mark S. Rea, Rensselaer Polytechnic Institute. *Illuminating Engineering Society of North America Lighting Handbook*. 2000.

APPENDIX B Energy use by miscellaneous equipment

Depending on the equipment present in the host company's building, there may be opportunities for energy savings in equipment beyond those discussed in Chapter 7. Lawrence Berkeley National Laboratory in California, USA, conducted an audit of 16 buildings and found that, in large offices (totaling 30,000 square feet or more), for every 2 kWh used by office equipment, another 1 kWh is used by miscellaneous equipment. The following are the top ten users of energy in their survey:

TABLE C.1: ENERGY USE BY MISCELLANEOUS EQUIPMENT

Rank	Miscellaneous equipment	Energy usage per year per unit (kWh/year)
1	Vending machines	3318
2	Commercial refrigerator	4300
3	Speakers	74
4	Ethernet switch	17
5	Commercial freezer	5200
6	Microwave oven	447
7	Fluorescent undercabinet lamp	33
8	Commercial coffee maker	1349
9	Coffee maker	450
10	Refrigerator (small)	277

If the host company is using a significant number of these machines, it may be advantageous to replace equipment with more energy-efficient versions.

Notes

M. Sanchez et al., Environmental Energy technologies Division, Lawrence Berkeley National Laboratory. "How plugged in are Commercial buildings?" February 2007, p.11. accessible at: http://enduse.lbl.gov/info/lbnl-62397.pdf

APPENDIX C HVAC background information

Unitary vs. centralized HVAC systems

Commercial buildings smaller than 1,850 square meter typically use factory-built, air-cooled "unitary" HVAC equipment. Buildings larger than 9,300 square meter and multi building campuses generally use site-assembled or engineered "centralized" HVAC systems. Buildings with a square footage between 1,850 and 9,300 square meter may employ a combination of multiple large packaged units (for example, one unit per wing of an office building) or small built-up systems. Performance comparisons between unitary and engineered systems, or among systems of either type, should consider the performance of the entire system, rather than just the chiller or the condensing unit.

The principal advantages of central HVAC systems are higher energy efficiency, greater load-management potential, fewer and higher-quality components that require less (but more skilled) maintenance, and architectural and structural simplicity. The main advantages of unitary systems are lower initial costs, independent zone control, lower failure risk, and less floor space occupied by a mechanical room, ducts, and pipes.

Performance measurements

There are a number of metrics that can be used to compare the efficiency performance of various HVAC systems. The Air-Conditioning & Refrigeration Institute (ARI) defines standardized test procedures to determine the efficiency metrics for a limited scope of HVAC systems. The tests used to evaluate the performance vary based on the HVAC equipment being tested. The following list summarizes major HVAC performance metrics:

Cooling capacity is rated as the amount of heat energy a cooling unit can remove from a space per hour, expressed in BTU per hour.

Energy Efficiency Ratio (EER) is the ratio of the cooling capacity (BTU/h) to the power input value (watts) at any given set of rating conditions expressed in BTU/watt-hour. The current standard is an energy efficiency ratio (EER) of 8.9 for systems with a capacity of 65 to 135 thousand BTU per hour (kBTU/hr).

Coefficient of Performance (COP) is defined differently depending on function. For cooling, COP describes the ratio of the rate of heat removal to the rate of energy input in consistent units, for a complete cooling system as tested under a nationally recognized standard. For heating, it is the ratio of the rate of heat delivered to the rate of energy input in consistent units, for a complete heat pump system as tested under designated operation conditions. Conversion: COP = EER * 3.4.

Note that both COP and EER are calculated under controlled laboratory conditions and usually do not reflect the efficiency of performance under actual use. The seasonal energy efficiency ratio (SEER) and the heating season performance factor (HSPF) address the need to reflect actual use by measuring efficiency in field situations.

Seasonal Energy Efficiency Ratio (SEER) is the total heat removed from the conditioned space during the annual cooling season, expressed in BTU, divided by the total electrical energy consumed by the air conditioner or heat pump during the same season, expressed in watt-hours. U.S. federal appliance efficiency standards currently require minimum SEER ratings of 13. The highest efficiency models available can have SEER ratings up to 23 for central air units.

Heating Season Performance Factor (HSPF) is the total heat added to the conditioned space during the annual heating season (expressed in BTU), divided by the total electrical energy consumed by the air conditioner or heat pump during the same season (expressed in watt-hours).

Integrated Part-Load Value (IPLV) is a seasonal efficiency rating method for representative loads from 65,000 BTU per hour and up. This rating applies to units that have stated partial capacities, such as units with staged compressors. Units are tested at full capacity and at each stated partial capacity, and those values are then used to calculate IPLV.

Additional information

For additional information on HVAC design, see:

Nontechnical introduction to HVAC: NCDEnr. 2003. “Energy Efficiency in industrial HVAC systems.” accessible at: *http://www.p2pays.org/ref/26/25985.pdf*

Technical discussion of HVAC systems: Benjamin, Reynolds, Grondzic, and Kwok. Mechanical and Electrical Equipment for Buildings, 10th Edition. John Wiley & sons, inc. new York.

Notes

[1] American Council for an Energy Efficient Economy (ACEEE). 2004. Online guide to Energy-Efficient Equipment. High-performing HVAC systems. accessible at: *http://www.aceee.org/ogeece/ch3_index.htm*.

[2] ERPI Office Complexes Guidebook, Innovative Electric Solutions.

Chapter 6—Heating, Ventilating, and Air-Conditioning (HVAC). December 1997. tr-109450, p. 195.

[3] Air-Conditioning and Refrigeration Institute. (2006). 2006 Standard for Performance Rating of Unitary Air-Conditioning Equipment and Air Source Heat Equipment.

APPENDIX D Building envelope measures

A well-designed building can reduce the heating and cooling load by up to 30%[1]. Advantages extend to a reduction in cooling and heating peak load, and in the capacity of HVAC installations and operating hours. These outcomes can be reached by adopting 'passive' design features or construction measures. The guiding principle is to reduce energy gains or losses through the building outer shell. Heat that is not gained or released does not need to be handled by the HVAC system. In other words, incoming solar heat that is prevented from going through the building does not need to be removed by a cooling installation. Similarly, heat that is prevented from escaping does not need to be generated by the heating installation. The ultimate goal is to achieve comfortable indoor temperatures for building occupants.

Thus an 'Energy Efficient Building' provides a more comfortable indoor climate, while minimizing use of the HVAC installation. Hence the operating time is reduced significantly, and so is the running cost of operation. In most parts of the Arab region, cooling is the main internal energy load of a building. Therefore, the recommendations in this appendix mainly address measures for reducing the cooling load.

This handbook considers mainly existing buildings. Therefore, design features will not be considered unless major renovations are planned. Nonetheless, how office space is used could be re-considered. This appendix considers, for instance, how use and occupancy of space are allocated and positioned in the building.

As far as the building envelope, which includes walls, windows, the roof, and the ground floor, it is recommended to consider initially easy measures that are more feasible to install. In addition, the measures that can be installed will depend on the type of occupancy. If the building is rented, the rental contract needs to be consulted to identify what alterations in the office space and to the building are permitted, if any.

Design Measures

Unless a major renovation is foreseen, possibilities to implement design changes are limited.
However, regarding office space use, there are identifiable measures that can be taken.

- Energy efficient use of space: Consider the relationship between the

1 Results of the Pilot Project in MED-ENEC -www.med-enec.eu/building-projects/pilot-projects

frequency of occupancy of a given office space, which dictates the heating/cooling load, and the location of such space. Space that has longer or high occupation rate, such as offices should be located toward the north side of the building. Space with short or intermittent use, such as conference or storage rooms, should be located toward the south side. Such an arrangement would expose high occupancy space to less sunlight, thus reducing the cooling load.

- Night ventilation: Keeping the windows open at night, during some time of the year, allows the building to cool down naturally. This allows the heat that has been trapped inside the building during the day to be released at night, and hence reduces the cooling load on the HVAC system by the start of the next day. Safety considerations must be taken into account:

❖ Windows that can be easily and safely kept open outside of office hours should be used in order to ensure that intruders cannot get access to the building. For example, the top part of a window or a small window opening can be utilized. Alternatively, 'safety grills' (traditional mashrabiya or 'hamiya') can be installed on the outside of windows to prevent entrance to the building.

❖ Special ventilation openings on opposite sides of the building can be used, allowing a natural air-flow through the building. This option is more secure.

- Light interior colors: It is desirable to use light colors (white, off white) in the interior to minimize heat absorption and cooling load. An added advantage to light interior colors is the reflection of more light inside the office which reduces the level of artificial lighting required.

Building envelop measures
Building envelope measures in existing buildings are designed to optimize energy transfer between the building and its surroundings, thus minimizing heat exchange between the indoor and the outdoors.

Light colors for the envelope: As mentioned above, light colors reflect more light and have a lower heat absorption rate. Repainting the whole building on the outside will require a monumental effort. Because it is exposed to the sun all day, the roof has a proportionally higher capacity to gain heat (to be avoided). The exposure to solar radiation causes the indoor space below the roof to heat up. Therefore, painting the building roof white is the most appropriate option to consider, provided the roof is not crowded with installed equipment such as water tanks or satellite dishes.

As a case study, a nongovernmental organization in Jordan was accustomed to operating the AC system at 2 pm, at which time the temperature rise was sufficiently high to warrant cooling. To reduce the heat gain from the roof, the organization had painted the roof of its headquarters white. As a result, the AC now is turned on by 4 pm, indicating a reduction in AC time use from 3 to 1 hour. The cost of painting the roof white was US$70 and required 2 days of maintenance staff work.

Shading: Windows are the 'weakest link' in the building envelope. Their thermal resistance to heat transfer is always lower than walls, regardless of the type of windows or glazing used. Shading avoids direct contact with solar heat and can reduce the cooling load significantly, especially for south-oriented windows. Windows oriented to the North side do not require shading (from an energy performance perspective).

Therefore, shading is almost a 'must' in regions with a hot climate. Care must be taken to ensure that shading does not restrict admission of day light into the indoor space by any appreciable degree. The litmus test is to not require additional artificial lighting. Louvres work best for this purpose, horizontal for south oriented elevations and vertical for east and west orientations.

Shading should be fixed on the outside of the building for best results. Lamella shading is the most cost effective. Movable shading is more appropriate for climates that require heating in the winter, but is usually more costly. In this case, the solar heat can help reduce the heating load.

Air tightness: Minimizing air leakage is most easily addressed by proper window sealing. Little openings between windows and walls or between windows' frames allow for significant exchange of heat between the indoor space and the outdoors. These openings should be sealed well. Depending on the wall (finishing) materials, this can be done with cement or silicone for openings between the wall and the window frame. For operable windows, foam of rubber strips can be fixed in the edge where the fixed and the operable window leave/meet each other. For sliding windows supply have so called ribbon brushes.

Double-glazed windows: Due to the air cavity between the glazing panes, double-glazed windows have a higher thermal resistance than those with a single glazing. Technically, it is easy to replace single glazing windows by double-glazing windows. However, this will be determined by the type of window used, frame type, and the material of construction (wood, aluminum, or PVC). In some cases, only the glass needs to be replaced. But in other cases, the window frame will need to be replaced to accommodate the larger thickness of a double-glazing window. Frame replacement will add to the cost.

Roof insulation: The roof gains most heating during the day from the sun. Therefore, insulating the roof reduces the cooling load and use of AC in the top floor. A layer of 3 to 5 cm of polystyrene works best. It is important to cover the insulation material with a sealing layer to prevent water intrusion (rain water reduces the insulation capacity of the material).

This measure requires more preparation if the roof contains installed equipment.

Wall insulation: If a major building renovation is planned, it is recommended to install insulation material (3-5 cm of polystyrene) in the walls. A well-insulated building gains heat at a much slower rate, hence reducing the cooling load.

Further information on building envelope insulation is available at:
http://www.med-enec.com/news/guide-maghr%C3%A9bin-des-mat%C3%A9riaux-d%E2%80%98isolation-thermique-des-b%C3%A2timents

APPENDIX E Water heating background information

A wide range of water heater types may be encountered in office buildings. The following is a description of water heater types excerpted from a Guide to Water Heating, published by the American Council for an Energy-Efficient Economy (ACEEE):

"**Storage tank water heaters** are the most common type of water heater in the U.S. today. Ranging in size from 20 to 80 gallons (or larger) and fueled by electricity, natural gas, propane, or oil, storage water heaters heat water in an insulated tank. When you turn on the hot water tap, hot water is pulled out of the top of the water heater and cold water flows into the bottom. Without proper insulation, storage tank water heaters can be energy inefficient because heat is lost through the walls of the storage tank (this is called standby heat loss) even when no hot water is being used. New energy-efficient storage water heaters have higher levels of insulation around the tank and one-way valves where pipes connect to the tank, substantially reducing standby heat loss.

Demand water heaters, also known as instantaneous or tankless water heaters, eliminate the storage tank by heating water when hot water is needed. The energy consumption of these units is generally lower since standby losses are eliminated. Demand water heaters with enough capacity to meet household needs are gas or propane-fired. They have three significant drawbacks for some applications: Large simultaneous uses may challenge their capacity. They will not turn on unless the hot water flow is 0.5 to 0.75 gal/minute. Retrofit installation can be very expensive.

Heat pump water heaters are more efficient than electric water heaters because the electricity is used for moving heat from one place to another rather than for generating the heat directly. The heat source is outside air or air where the unit is located. Refrigerant fluid and compressors transfer heat into an insulated storage tank. Heat pump water heaters are available with built-in water tanks called integral units, or as add-ons to existing hot water tanks. A heat pump water heater uses one-third to one-half as much electricity as a conventional electric resistance water heater, and in warm climates they may do even better. Unfortunately, there are few sources for these products.

Indirect water heaters generally use the boiler as the heat source. In boiler systems, hot water from the boiler is circulated through a heat exchanger in a separate insulated tank. In the less common furnace-based systems, water in a heat exchanger coil circulates through the furnace to be heated, then through the water storage tank. Since hot water is stored in an insulated storage tank, the boiler or furnace does not have to turn on and off as frequently, improving its fuel economy. Indirect water heaters, when used in combination with new, high efficiency boilers or furnaces, generally have the lowest operating costs among water heating technologies.

Solar water heaters use energy from the sun to heat water. Solar water heaters are designed to serve as pre-heaters for conventional storage or demand water heaters. While the initial cost of a solar water heater is high, it can save a lot of money over the long term. On a life-cycle cost basis, solar water heaters compete very well with electric and propane water heaters, though they are still usually more expensive than natural gas."

Central vs. distributed equipment

The decision to use a central or distributed water heating system impacts requirements for on-demand heaters, pipe insulation, application and building design.

Example: Central vs. distributed application

If a central hot water system is employed and hot water is needed in a bathroom that is 50 feet from the natural gas hot water storage tank, the 50 feet of water volume in the pipe will have to be drained in order to get to the hot water. If the pipe has a 3/4-inch diameter it will hold 4.6 gal in 50 ft. If the water heater is set at a level of 120ºF and incoming water is 50ºF, the 4.6 gal of wasted water will also waste 2,682 BTU when it is heated. One option around this loss would be the installation of tankless heaters adjacent to the hot water applications. This would avoid the loss of 4.6 gal as well as the 2,682-BTU loss. However, if there is a large capacity need, the instantaneous demand for energy could lead to electric cost penalties or difficulty meeting large delivery needs. (Adapted from Stein, Mechanical and Electrical Equipment Buildings 9th ed. Page 601–603.)

Additional information

For U.S. and California appliance efficiency standards see:

Appliance Efficiency Regulations. Dec 2006. CEC-400-2006-002-rEV2. Accessible at:
http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-rEV2.PDF

For an introduction to facilities water management, see:

James Piper, Maintenance Solutions. "Water Use: Slowing the Flow." 2003. Accessible at:
http://www.facilitiesnet.com/ms/article.asp?id=1969&keywords

For a technical reference on hot water systems, see:

Benjamin Stein and John Reynolds. 2000. Mechanical and Electrical Equipment for Buildings, Chapter 10, Water Supply. Sections 10.5, 10.6, and 10.7 containing Water Sources, Hot Water Systems and Equipment, and Fixtures and Water Conservation. Accessible at:
http://www.facilitiesnet.com/ms/article.asp?id=1969&keywords

Notes

ACEEE—American Council for an Energy-Efficient Economy, "Consumers Guide to Home Energy Savings: Condensed Online Version." Water Heating. Accessible at:
http://www.aceee.org/consumerguide/waterheating.htm

APPENDIX F Case studies

CASE STUDY 1: University Classrooms

CASE STUDY 2: Solar Photovoltaic Power for Public Schools in Lebanon

CASE STUDY 3: Biodiesel in UAE from McDonald's Waste Oil

CASE STUDY 4: Aramex Dubai Logistics City: LEED Gold Certified with Philips Lighting

CASE STUDY 5: Aqaba Residence Energy Efficiency (AREE)

CASE STUDY 6: The Arab Organizations Building in Kuwait

CASE STUDY 7: Central Bank of Lebanon Goes Green

CASE STUDY 8: Dubai Festival City Hotels: Energy Efficient Landmark

CASE STUDY 9: Eco-Friendly Stadiums in Qatar

CASE STUDY 10: Energy-Saving Lamps in Lebanon

CASE STUDY 11: Energy Efficiency Retrofit for a Hospital

Case Study 1

University Classrooms

Large classrooms for computer training at a Lebanese university are equipped with 36 of 4x36 W TFL8 lighting fixtures. Night time illumination levels reached 600 LUX when all lights were ON. IESNA and CIBSE requirements require generally a maximum of 300 LUX for such applications.

One suggested option was to ask the students to energize 4 out of 6 lighting circuits (the 36 fixtures being zoned into 6 circuits). Delamping was also suggested as an alternative. Delamping was adopted because LUX readings have shown that de-energizing 2 tubes from each fixture would result in more uniform lighting levels than switching off two circuits out of 6.

Consequently, two tubes from each other fixture in staggered order were de-energized by disconnecting their ballasts. Readings were now lower than 400 LUX. The annual energy savings from this intervention were estimated at 2400 kWh which translates into 8400 kWh or 0.72 ton of oil-equivalent (TOE) of primary energy based on Lebanon's electric utility conversion efficiency. Avoided CO_2 emissions were 2.4 Tons. The payback period was 1 month.

Case Study 2

Solar Photovoltaic Power for Public Schools in Lebanon

Reliable energy is critical for economic growth, social development, fiscal sustainability, and regional and global integration. Indeed, several studies undertaken by the World Bank in many countries show a very clear correlation between access to energy and gross domestic product (GDP) growth.

Although Lebanon is 100% electrified, most regions of the country, mainly near the borders, suffer from very long electricity black-out periods and have very low voltage levels, which doesn't enable them to use electrical appliances or even enjoy adequate lighting levels.

While generally an inconvenience for everyone, for children these black-outs can have negative effects, particularly on their education. Since public schools cannot afford adequate alternative energy sources, children have no access to sufficient lighting or to reliable power to permit the use of classroom technologies.

With a mandate to deploy sustainable energy projects in Lebanon, the country energy efficiency and renewable energy demonstration project for the recovery of Lebanon (CEDRO), which is managed by the United Nations Development Program (UNDP), initiated in 2010 projects for the installation of solar photovoltaic (PV) systems in 25 public schools and community centers in Akkar, Bekaa, and in the South. Kherbet Selem public school in the south of Lebanon was selected for the pilot project.

The solar PV system is designed to supply power to the school independent of the grid. However, it is connected to the grid to allow the system's batteries to be charged when they are low on stored energy. In the future, a feed-in option will be installed to allow the solar PV system to supply power to the public grid during school days off or when there is power surplus.

The installed solar PV system consists of three mono-crystalline modules and has a capacity of 1800 Watt-peak (W_p). The solar modules comprise of cells that produce electrical direct current (DC) when exposed to sunlight. The electricity produced is stored in batteries and then converted to alternating current (AC) by an inverter. The batteries will supply essential power load to the building in the event of a grid power failure. The amount of power supplied will be sufficient to meet the load requirements of all necessary electrical equipment. In addition, more efficient lighting fixtures have been installed to provide the same required illumination for classrooms and offices, while consuming less energy.

The back-up batteries are required to provide uninterrupted power supply in the case of a grid failure. Therefore, the solar PV system will work as the school's own generator and will supply the essential load. When solar radiation is low, power will be withdrawn from the public grid to charge the batteries. When the school is not occupied, during 3 months of the year, it will be possible for the solar PV system to feed renewable power into the public power grid.

Case Study 3

Biodiesel in UAE from McDonald's waste oil

Neutral Fuels, a company specialized in energy-efficient operational solutions, has begun to produce biodiesel by converting vegetable oil from local McDonald's restaurants in the United Arab Emirates. The biodiesel produced is used to fuel McDonald's logistics trucks, and can be used by any normal diesel engine. The oil received from McDonald's is the waste from food preparation, and therefore reduces carbon emissions by 60 to 80% as compared to traditional diesel fuel.

This biodiesel program is not the first of its kind, as it is already in operation by McDonald's in Germany, the UK, and areas in Brazil and the US. The process works better in the UAE, though. Robin Mills, a Dubai-based energy analyst, explained in an interview with the BBC that the danger of biodiesel is that there is the possibility of it clogging up, forming a gel and eventually freezing at low temperatures. Of course, low temperatures are not a problem in the UAE, thus eliminating this risk.

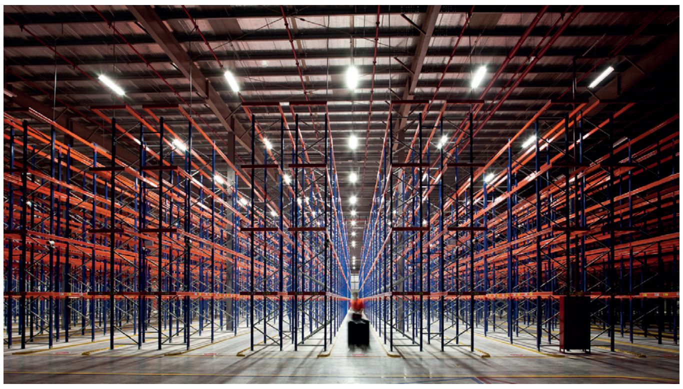
One problem the country does face is that the UAE subsidizes the price of fuel at the pump, making it harder for companies like Neutral Fuels to compete and make a profit. Nonetheless, chairman of Neutral Fuels Karl Feilder takes this as an opportunity "to be even more efficient and even more competitive."

The UAE is the world's eighth largest oil producer, rendering it quite surprising that the biodiesel project is gaining support. Other restaurant chains are beginning to express an interest in the program as well.

"Nowadays companies are becoming more environmentally conscious and they want to, as much as they can, be environmentally sustainable," says Abdulla Al Jallaf, managing director of Neutral Fuels in Dubai, which became the first commercial producer of 100% biodiesel in the Middle East. The operation has been supported by Dubai Government's Department of Economic Development (DED). McDonald's is currently Neutral Fuels' only client and the project is restricted to the UAE, but there are hopes to expand the project across the wider region.

Case Study 4

Aramex Dubai Logistics City: LEED Gold Certified with Philips Lighting



As a 29-year old global provider of comprehensive logistics and transport solutions in more than 54 countries, Aramex understands the importance of warehousing within the wider supply chain, and the environmental footprint of those facilities. The company is investing in cutting-edge green technology to ensure meeting customers' storage requirements and inventory management needs with minimal carbon footprint. Dubai Logistics City emerged as one of Aramex's key facilities to become energy efficient under "A LEED Gold Certified" project, in partnership with Philips.

The challenge was to provide a simple yet smart lighting solution to meet the application requirements, while consuming 40% less energy than stipulated by ASHRAE standards. The project required luminaries-based, stand-alone lighting controls for occupancy detection in the warehouse area and daylight optimization in the offices.

Philips made an intelligent selection and customization of standard luminaries. For the lighting controls, it customized the standard TMX204 luminary with an occupancy sensor in the warehouse area to provide the ideal scenario: light when and where needed. The Smartform TBS460 luminaries in the office spaces have been fitted with Luxsense controllers, which save energy by automatically regulating the luminary in accordance with the level of daylight available. Fugato Compact and Performance downlights with PL-R lamps were used for circulation areas.

Dubai Logistics City project reflects Aramex's continuous commitment to reduce its carbon footprint, optimize power consumption, and raise awareness among other activities in its 307 locations around the globe.
Both Aramex and Philips are AFED corporate members.

Case Study 5

Aqaba Residence Energy Efficiency (AREE)

The Aqaba Residence Energy Efficiency (AREE) is a three-floor, 420 m^2 building that includes a living room, a kitchen, a study room, a family room, six bedrooms, three bathrooms, a car garage, and a basement. The design addresses the efficient use of resources in building construction and in water and energy consumption.

The summer temperatures in Aqaba rise above 40º C, and with hardly a need for heating during the winter, the design was focused on adopting passive cooling strategies. By design, heat accumulation is prevented in the summer and heat gain is optimized in winter. The architectural concept was formed by sun angle analysis, wind conditions, Red Sea views, and Jordan's common construction practices (plastered block work and stone cladding).

The architectural design is the first step to get to efficient use of energy, water, and materials. The orientation and layout of AREE optimize passive cooling. Spaces that are generally used for short periods (bathrooms, garage, corridors) are located on the southwest side, the hottest side of the house, creating a buffer that helps keep the main spaces cooler. To minimize the internal cooling load, the bedrooms face northeast. The main part of the building is finished in plasterwork mixed with straw to decrease heat transfer and reduce the use of cement. The use of plasterwork provides a nice texture that improves with ageing.

Natural ventilation is improved by carefully positioning the windows, doors, and ventilation openings below the ceiling and the main staircase, designed to work as a 'wind tower'. Movable shades prevent solar warming in the summer time, but allow for solar heat to enter during the winter to minimize the need for heating.

Exterior and interior space is connected by a zone with recessed glass doors for optimal day lighting. This zone, housing the kitchen and dining area, connects both building volumes. The lower volume is clad with recycled stone procured from local stone companies. The roof garden on top of the lower volume contributes also to a lower internal cooling load achieved by the heat accumulation capacity of the 40-cm garden soil. This roof garden provides shading and has a beautiful view of the Red Sea.

The building envelope is the second step for environmental design and passive cooling strategy. Interior spaces are protected from solar heat through the use of improved insulation. The blocks of the cavity walls have a better insulation value because of the volcanic and perlite aggregates. The cavity is filled with insulation material. The most exposed building surface is the roof, and therefore it is also insulated, which is not a common practice in Jordan. Another new practice introduced is the insulation of the 'thermal bridges' at the floor-wall connections. The sand filling of the north cavity wall and natural stonewall finishing increase the heat accumulation capacity of the building.

The building design and construction save 30% on the cooling load, compared to a conventional building. To ensure significant savings on electricity bills, efficient lighting systems have been installed as well.

The 'solar cooling' concept is based on hot water from solar panels providing thermal energy to the adsorption chiller, which provides chilled water to cool the interior. This is the first application of solar cooling in Jordan, and therefore there are challenges in achieving optimal performance. The local supplier is working on a second prototype. In the meantime, an imported adsorption chiller has been installed and is currently being tested.

The solar cooling system brings the total potential savings of electricity costs to 72%, compared to a conventional design. Taking in consideration additional investment costs, the expected payback time is less than nine years. To make AREE almost self-sufficient in energy supply, the option of photovoltaic (PV) panels for electricity generation was considered. However, the long payback time of around 14 years rendered this option uneconomical.

All design and construction elements were easy to plan on the drawing board, but required a lot of discussion with the engineers and contractors on site. The biggest challenge for sustainable building in Jordan is the use of materials and the reduction of construction waste. Environmentally friendly materials are scarce and local suppliers are often unfamiliar with material specifications. Moreover, Jordanian contractors were not familiar with passive cooling strategies. The opportunities for learning have been immense, which bodes well for the dissemination of more sustainable building practices in Jordan.

More information about AREE is available at: *http://www.med-enec.com/building-projects/pilot-projects*

Case Study 6

The Arab Organizations Building in Kuwait: An Example of Modern Eco-friendly Architecture

Among glass high-rise buildings that have invaded the Gulf countries stands a unique building in Kuwait: the Arab Organizations Headquarters Building, a model of modern environmentally-friendly construction. The building, which is home to the Arab Fund for Social and Economic Development, adapts the traditional Arab house design which is built around a courtyard. Therefore, all the offices in the building overlook the spacious central courtyard which carries nature inside. The splendor of the interior is not reflected on the exterior of the building which is seen from a few kilometers as a massive cube of gray granite covering 54,000m^2, and dotted with deep slanting openings on all sides.

As you enter the building, which was completed in 1994, you feel like swimming in the light. You do not feel any draft blowing from air conditioners, nor do you feel any disturbing heat. Special insulation and lighting systems have created, inside the building, a temperate and comfortable environment. This eco-friendly building consumes less than half the quantity of energy used in any other glass building of the same size. In addition to having all these environmental qualities, the building is an embodiment of modern architecture with all its advanced technologies.

Upon entering the building, a visitor is overwhelmed by its grandeur, extensive dimensions, and lofty heights. One can sit calmly for hours in the waiting room with nothing to hear but the trickle of water from the fountain and nothing to see but stunning scenes around. Attention is immediately drawn to the left side where there is a great waterfall over a Moroccan, light-colored, hand-made mosaic wall.

On climbing the marble stairs that lead from the Moroccan waiting room to the first floor, one would start to hear a melody coming from above mixing the twittering of birds with the gurgling of water. Once on the first floor, your eyes are caught by extended greenery, bright light and ample space. This is the building's main courtyard, an architectural feat manifesting both artistry and power.

Walls and partitions on all floors are made of glass, making it possible for anyone standing at one end of the building to look through to the opposite end easily.

A critical design challenge was to exclude excessive exterior heat while retaining natural light. This was achieved after a careful study of the sun's rays that reflect on the building throughout the year. The windows were designed in directions that do not allow direct sunlight into the building, and artificial lighting was made in a way that gives daylight effect without shades. The glass wall of the courtyard is unobstructed from the north to allow light in while blocking direct sun rays.
The concept, design and execution of the Arab Organizations Headquarters Building is a striking proof of the success of employing modern architectural techniques adapted to local environments at an age when imitation and copying prevail.

Case Study 7

Central Bank of Lebanon Goes Green

The Central Bank of Lebanon (BDL) is subsidizing green loans, which consumers can apply for at an affordable interest rate of about 2% over the cost of funds. Managed by commercial banks, the loans were initially meant to support eco-friendly industry and agriculture, but have been extended to support green construction, eco-tourism, and even the renovation of existing facilities to preset environmental standards. To broaden the scope of the initiative, BDL and the United Nations Development Program (UNDP) have agreed to establish the National Energy Efficiency and Renewable Energy Action (NEEREA) to finance energy efficiency, renewable energy, and green building projects across Lebanon.

To facilitate collaboration, BDL and UNDP signed a Memorandum of Understanding (MOU) on June 14, 2010. Using the MOU as a framework for cooperation, DBL and UNDP seek to bring in international donors and organizations to support NEEREA. The two bodies will also organize awareness-raising and capacity-building programs targeting Lebanese commercial banks and consumers to promote energy efficiency and renewable energy projects.

To facilitate loan processing, NEEREA will develop a set of criteria to assess the technical eligibility of green loan applications. These criteria will be used to provide technical validation and certification to potential green projects submitted to BDL through the Lebanese Center for Energy Conservation (LCEC), hosted at the Ministry of Energy and Water.

In parallel, the European Union has signed a €15 million grant contract with BDL and the soft loan program *Kafalat*, geared at providing financing to small and medium size enterprises (SMEs) that want to invest in energy efficiency and renewable energy technologies.
NEEREA is expected to leverage investments in the range of US$500 million in the coming few years in order to finance projects with interest rates as low as 0% and repayment periods reaching 14 years, with variable grace periods.

Case Study 8

Dubai Festival City Hotels: Energy Efficient Landmark

InterContinental & Crown Plaza hotels in Dubai Festival City comprise 814 rooms, with over 2 kilometers of static external façade lights and more than 35,000 indoor light points. The existing lighting installation was inefficient, causing high maintenance costs, high rates of heat release from lit lamps, and high energy consumption.
To identify opportunities for switching to energy saving solutions, Philips performed a lighting audit at the premises. The audit results have revealed that the old installation could be replaced with a more efficient lighting system that would ensure long term safety, while preserving the ambience of the rooms and corridors by using the appropriate lamp for the right application.
For interior lighting, a direct replacement with light-emitted diode (LED), CFL-I, and energy saving halogen lamps was offered based on the application requirements and location (burning hours, light levels, and dimming needs). This solution has reduced heat generation, which in turn reduced the cooling load, and has improved the quality of light especially in the corridors. Maintenance costs have become minimal due to the long lifetime of the new lighting installation, particularly the LED technology.
Likewise, a feasibility study of outdoor lighting demonstrated that maintenance-free LED I-Color Accent is the perfect alternative to the cold-cathode tubes. Flexibility of control, provided via an easy plug & play system, allows playing any color-changing effect in line with the type of event taking place on the premises.
InterContinental and Crowne Plaza in Dubai Festival City are setting the benchmark for one of the region's best practices in green technology. Aiming to reduce their carbon footprint, the hotels are expected to cut down their CO_2 emission by almost 2 million kg/year and achieve an 80% reduction in the energy costs incurred by lighting.

Case Study 9

Eco-Friendly Stadiums in Qatar

Qatar won its bid to host the 2022 World Cup Finals, but will players and spectators be able to endure the scorching Doha summer? And who will later, in this tiny country, make use of stadiums built to accommodate tens of thousands of spectators? And what will the magnitude of this tournament's ecological footprint be? Qatar pledged to have a carbon-free tournament but the question is whether it will be able to fulfill its promise.

Qatar undertook to use and develop eco-friendly technologies that could later be adopted by other countries. After the end of the finals, the stadiums will be contracted by dismantling some parts and shipping them to, and reassembling them in, other Asian countries. This will help keep the spirit of Qatar 2022 alive across the continent. Visitors from all over the world will enjoy Arabian hospitality and leave Qatar with a new understanding of the region.

The main challenge facing the organizers is to overcome the extreme desert heat in summer when the finals are taking place. Providing a comfortable environment inside the stadiums requires too much energy, especially for cooling. Two solar energy technologies shall be applied simultaneously to guarantee a convenient and carbon-neutral environment for all players, fans, administrators, and the media. The first technology is the photovoltaic system that converts sunlight into electricity. The second is the solar thermal system that uses heat captured from the sunrays. The system's collectors transmit and store energy to be used on the days of the matches to cool the water which, in turn, cools the air down to 27° C. Cold air shall be carried, through tubes, to the ground of playing fields and under seats to cool players and watchers alike. Though these two systems are not new, it is the first time they are used in combination with each other.

The roofs of the stadiums shall be retractable to comply with the FIFA regulations which might require matches to be played in open air. Roofs shall be closed during the days before the matches to keep the temperature in the stadiums at 27º C. When there are no matches in the stadiums, the solar equipment shall transmit electricity to Qatar's main grid, and receive its power from the same grid during matches, making the stadiums carbon neutral.

These cooling technologies shall be made available to other countries that have hot weather, so that they may also host major sports events.

Engineers at Qatar University's Mechanical and Industrial Engineering Department produced a design for an artificial cloud that is remotely controlled, so that its location may be changed depending on the position of the sun. Such a cloud shall hover above the stadium and overshadow all fans sitting to watch the game. The cloud consists of a mixture of light carbon and helium, and the solar energy will keep it floating in the air.

Qatar's pledge to adopt the green building standard was part of its national 2020 vision, and not solely to support its World Cup bid. If the Green Building Council and construction companies succeed in implementing environmental principles during the next few years, Qatar might witness, by 2022, the development of highly-advanced building technologies. Yet the great challenge will be to shift these technologies from sports spectacles to everyday life.

Case Study 10

Energy-Saving Lamps in Lebanon

On March 10, 2010, the Government of Lebanon approved the national action plan submitted by the Ministry of Energy and Water (MEW) to allocate US$9 million to finance energy conservation programs in the country. The allocation was diverted from a budget initially assigned to subsidize diesel fuel. One of the main goals of the plan is to replace, free of charge, 3 million incandescent lamps, with 3 million compact fluorescent lamps (CFL) in households across Lebanon, at a cost of US$7 million.

CFL lamps have been demonstrated to have lower power consumption than incandescent lamps while costing less over their lifetime. They also provide effective illumination. The replacement program will be part of an effort to phase out incandescent lamps. One million residential electricity subscribers, out of a total of 1.4 million, will benefit from this plan and will take part in this first-of-its-kind Clean Development Mechanism (CDM) project. The initiative is accompanied by an awareness campaign urging the public to adopt energy conservation measures.

The project is rolled out as per the Clean Development Mechanism (CDM) procedures in order to claim CO_2 reduction credits. The savings according to CDM calculations are 970 GWh of electricity, equivalent to US$181 million. CO_2 emissions will be reduced by 806,000 tons. In addition, the project will reduce the load demand by 160 MW of capacity at peak load. The reduction in peak load demand translates into crucial savings for the government's public budget. The public will benefit from reduced air pollution emissions as well as from lower energy bills.

Distribution of the CFLs has already started in October 2010, and will be completed in 6 phases. Public stakeholder consultation meetings have been conducted in each area of the country while simultaneously conducting an awareness campaign. The lamps are being distributed across Lebanon through municipalities and in collaboration with collectors of electricity bills at Electricité du Liban (EDL).

Case Study 11

Energy Efficiency Retrofit for a Hospital

The Centre Hospitalier du Nord (CHN) is a private hospital with 140 beds, located in Zgharta, North Lebanon. Due to frequent power cuts, 75% of the hospital's electrical energy demand has to be produced by generators. The total energy bill was over €270,000 in 2006. The CHN decided to conduct an energy audit that resulted in the following recommendations:
- Improved maintenance of air-conditioning (AC) equipment - Energy efficient lighting - Thermal insulation of the roof - Demand management system (software for peak shaving and control/monitoring).

After implementing the above measures in 2007, the hospital now saves 20% of its overall energy consumption. This corresponds to an annual saving of €55,000 of energy costs and a yearly reduction of 410 tons of CO_2 emissions. The needed investment did not exceed €60,000. The payback time being estimated at slightly above one year, the used technologies are replicable in most hospitals and similar buildings in Lebanon and in other countries in the region, even without any external financial assistance. CHN has already decided to use the positive experiences of this pilot project for a new hospital building in Jounieh, a coastal city north of Beirut.

Energy in Lebanon: Lebanon is extremely dependent on energy imports—about 97% of all energy had to be imported in 2005. Buildings are the second biggest energy consumers with a share of about 30%, with transport coming in first place and industry in third place. With the sharp increase in world market prices for energy, and with energy prices subsidized in Lebanon, the national electricity company **Électricité Du Liban** (EDL) alone absorbed 21% of the state budget in January 2008 (L'Orient Le Jour, 11/03/08). Moreover, people suffer from frequent power cuts due to insufficient and obsolete power plants and distribution lines and have to bear significant additional costs for private generators.

At the same time, a large potential for energy efficiency and for the use of renewable energies stays untapped in Lebanon. The building stock and particularly new buildings usually do not integrate technologies such as thermal insulation of the building envelope, energy efficient lighting, or solar water heaters. The project in Lebanon shows that with additional investments of 10-20%, energy consumption can be reduced dramatically by up to 60%. More information about the Centre Hospitalier du Nord is available at:
http://www.med-enec.com/building-projects/pilot-projects

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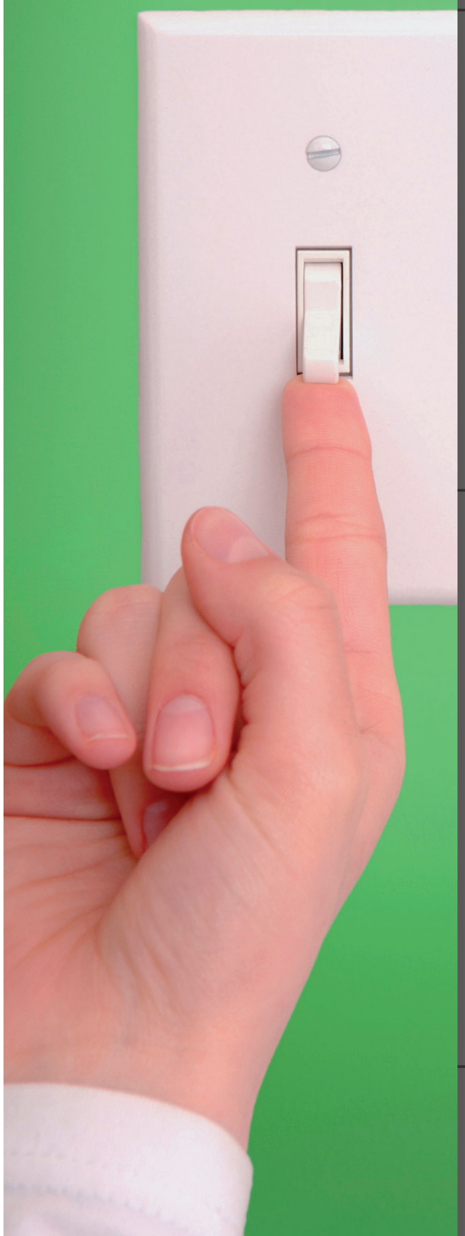

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