Energy Management and Economics

Tay Cher Seng

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Foreword

Singapore has joined the world community in pledging at the UN climate change talks in Paris (the 21st Conference of the Parties, or COP 21) to reduce greenhouse gas emissions and limit global warming. In the December 2015 conference, Singapore has made a commitment to reduce our Emissions Intensity by 36% from 2005 levels by 2030, and stabilise our greenhouse gas emissions with the aim of peaking around 2030. Given Singapore's limited access to renewable energy, this pledge is an ambitious one. It will require the concerted effort by all stakeholders, including the government, businesses, households and individuals to achieve this target.

The Singapore Certified Energy Manager (SCEM) programme is targeted at engineers and managers who manage manufacturing facilities and buildings and provide energy services or engineering consulting services. The role and responsibilities of the SCEM, as the appointed energy manager, to lead and execute the energy management system cannot be over emphasized.

I hope that this book on "Energy Management and Economics" will go some way in the training of the SCEM and contribute to our meeting the emissions reduction target.

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Preface

This book is organised in three parts:-

I. Energy Management System
II. Overview of the Energy Market in Singapore
III. Economic Analysis in Energy Efficiency Investments

In Part I, we deal with the energy management system (EnMS) which allows an organisation to plan, manage, measure, and continually improve the energy performance of its facilities. The following key components of the energy management system are discussed:

a. Roles and responsibilities of energy management team members
b. Energy policy
c. Energy objectives and energy targets
d. Energy efficiency improvement plan
e. Monitoring, measurement and analysis

These topics will be covered in Chapter 1 to Chapter 9. At the end of this first part, the reader should be able to successfully perform the following:

1. Develop an energy management system;
2. Define roles and responsibilities of energy management team members;
3. Conduct energy planning process, develop an energy policy, set objectives and targets, and develop action plans; and
4. Integrate energy management system into business practice.

Part II provides an overview of the energy market in Singapore. This is a subject that is dynamic. New policies and guidelines are announced by the authorities just as new players enter the energy market. With each development, the energy manager has to strategise how the procurement of energy supply might be optimised for the organisation. The materials are covered in Chapter 10 and Chapter 11. In this context, the energy manager's roles include the following functions –

a. taking advantage of fuel-switching and load management opportunities;
b. negotiating or advising on major utility contracts;
c. developing contingency plans for supply interruptions or shortages; and

d. forecasting and budgeting for short and long-term energy requirements and costs.

At the end of Part II of the book, the learning outcome is:

5. Understand Singapore's energy market tariff structure to enable better evaluation of supply contracts for reducing energy costs

As most energy management activities are dictated by economics, the energy manager must have good financial literacy. Besides making a technical appraisal of the energy efficiency project, the energy manager has to assess that the project is economically viable. The viability of a project hinges on the return on investment that the project can yield. The energy manager has to determine how much funds are needed to invest in the project and how much it will cost to raise this amount of money. He has to make an assessment of the financial risk of the project and weigh this against the reward.

The last two of seven learning outcomes are covered in Chapter 12 and Chapter 13 of the book. At the end of Part III, the reader should be able to:

6. Evaluate the financial attractiveness of energy retrofit projects; and
7. Understand the various energy performance contracting models.

At the end of each Part, the reader should reinforce the learning by attempting to work out the exercises. The solutions to some of the problems are provided at the end of the book for the reader's reference.

Acknowledgements
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Part I –

Energy Management System

1. Introduction to Energy Economy

1.1 Introduction and Learning Outcomes

Introduction

Engineers are trained to design any system and select any equipment to meet the worst case scenario. For a central chilled water system, the engineer might size the chillers to cool the building or facility on the hottest day of the year or when production levels are run at full capacity. The question is how often does this happen? The peak load scenario probably occurs only on a single-digit percentage of the time the chiller is run. This means the chiller, if it was selected to be at its best efficiency under peak load scenario, will only be running at optimal efficiency for a small percentage of the time. For the other ninety-odd percent of the time the chiller is operating under part load conditions. How would the chiller perform under this part load condition? This is a challenge the energy manager faces, deciding at what load the chiller will perform at its optimal best. How would he create the conditions for this to happen so that the chiller is run at optimal efficiency for the majority of the time? The organisation has to manage this challenge as it embarks on the road to continual improvement.

In Part I of this book, we introduce the energy management system (EnMS) as a tool for an organisation to plan, manage, measure, and continually improve the energy performance of its facilities. Chapter 1 first gives an overview of the energy economy. The energy management system will be discussed over the next seven (7) chapters. Chapter 9 will focus on how the Singapore government is leading the drive to achieving Singapore's commitment of reducing greenhouse gases and improving our energy intensity by 36% from 2005 levels by the year 2030.

Learning Outcomes

At the end of this first part, the reader should be able to:

1. Develop an energy management system;
2. Define roles and responsibilities of energy management team members;
3. Conduct the energy planning process, develop an energy policy, set objectives and targets, and develop action plans; and
4. Integrate energy management system into business practice.

1.2 The Energy Economy

Over the past century, economic activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. Most of the greenhouse gases come from burning fossil fuels to produce energy. Certain agricultural practices also release significant amount of greenhouse gases into the atmosphere. Greenhouse gases act like a blanket around the planet, trapping energy in the form of radiation in the atmosphere and warming it. We call this phenomenon, the greenhouse effect. Rising global temperatures have been accompanied by changes in weather and climate. Many places have seen changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves. Scientists have also noted the sea levels rising. This poses an existential threat to coastal cities like Singapore. The choices we make today will affect the amount of greenhouse gases we put in the atmosphere for years to come.

Going forward, some trends are shaping the energy economy. These are:

i. increasing demand for energy (especially clean energy)

ii. growing diversification of energy sources, and

iii. increasing efficiency of energy use.

For many decades we have seen growth in energy demand driven by population growth and economic activities. The world's population has grown from 4 billion in the 1970s to 7.1 billion[1] in 2013. This is expected to grow by 0.9% per year on average, to 9 billion in 2040. The increase in the global population is concentrated in Africa, India, South East Asia and the Middle East. Economic activity as measured by the GDP (gross domestic product), has risen in tandem with population growth. One trend that has emerged is that populations are increasingly concentrating in cities and towns, pushing the urbanisation rate up from 53% in 2013 to 63% in 2040[1], meaning that the absolute number of people living in rural areas will fall. Urbanisation tends to raise the levels of income, and economic activity tends to be higher leading to increased demand for modern forms of energy as such electricity.

[1] Source: World Energy Outlook 2015 published by IEA

Energy resources can be classified as either (1) renewable resources, which have the potential to regenerate in a reasonable period or (2) non-renewable resources, which have definite, although sometimes unknown, supply limitations. Resources used most in industrialized countries are non-renewable. It is worthy to note that renewable does not mean an infinite supply. For instance, hydropower is limited by rainfall and appropriate sites, usable geothermal energy is available only in limited areas, and crops are limited by the available farm area and competing non-energy land uses. Other forms of renewable energy also have supply limitations.

Non-renewable resources of energy include

i. Coal
ii. Crude oil
iii. Natural gas
iv. Uranium or plutonium (nuclear energy)

Renewable resources of energy include

i. Hydropower
ii. Solar
iii. Wind
iv. Geothermal
v. Tidal power
vi. Ocean thermal
vii. Biomass (wood, wood wastes, municipal solid waste, landfill methane, etc.)
viii. Atmosphere or large body of water (as used by the heat pump)
ix. Crops (for alcohol production or as boiler fuel)

As we become more conscious of the need for clean energy, many countries are trying to diversify the sources of energy they consume. China is making great efforts to harness wind energy. Europe, on the other hand, has made great strides in tapping solar energy. At the last count in 2015, Germany has installed the most photovoltaic capacity; about 39,698MW. However, energy from bio-fuel and geothermal sources remain modest. In the near future, the projection remains that the main sources of energy would still be coal, oil and gas. The contributions of hydroelectric dams and nuclear power stations will remain low.

For Singapore, solar power is perhaps the most obvious renewable source of energy for generating electricity. With an average annual solar irradiance[2] of 1,150 kWh/m^2/year and about 50 percent more solar radiation than temperate countries, solar photovoltaic (PV) generation has the greatest potential for wider deployment in Singapore.

Deployment of solar energy brings about several benefits to Singapore.

i. Solar energy generates no emissions, which contributes to environmental sustainability.
ii. Solar energy reduces reliance on import of fuels, which in turn enhances Singapore's energy security.
iii. Solar energy can reduce peak demand. This is because the peak energy usage in Singapore – typically in the afternoons – coincides with the periods when solar energy can be maximised. So lowering peak demand can potentially reduce electricity pool prices and bring benefits to consumers.

There has been some progress made in this area. As at 2015, Singapore was already harnessing almost 60 MWp[3].

[2] Source : Energy Market Authority, Singapore

[3] MWp refers to megawatt peak, which is a typical measure of the installed nameplate capacity for solar PV system; the term also represents the amount of electric power that can be produced by a solar PV system at its peak.

Figure 1: Solar PV panel on the roof top of high-rise buildings

However, there are two limitations to how much further Singapore can deploy solar power on a large scale to generate electricity reliably:

i. Singapore's small physical size (716.1 km^2), high population density and land scarcity limit the amount of available space to harness solar energy; and
ii. any power system with significant penetration of solar energy for electricity generation must manage intermittency appropriately, so as not to compromise grid stability.

Next, we examine the trend for greater efficiency of energy use. In fact, the energy we save from using energy efficient equipment becomes the cheapest, cleanest and most reliable source of energy. For example, we can save energy through the usage of more efficient water heaters, refrigerators or air conditioners, year in year out over the life of the equipment. Energy efficiency measures and their costs vary widely. Using an energy-efficient light bulb is a simple and cheap solution, while using a heat pump would cost more. Unfortunately, energy efficiency is sometimes confused with "doing without". People do respond in an acute crisis to appeals to change their habits and to monetary incentives to turn off the lights and turn up the thermostat on the air conditioners. That should be called "conservation" and it is quite different from “efficiency” even though the two words are often used interchangeably. Efficiency is about providing the same service using less energy.

A frequently quoted example is how California has set itself apart from the rest of the United States of America (USA) by being energy efficient. Figure 2[4] shows the state keeping the per capita electricity consumption nearly flat over the last 40 years while per capita energy consumption in the rest of the USA increased by over 50 percent. On a per capita basis, a Californian uses 6,721 kWh per year while other Americans use over 12,000 kWh per year. Efficiency efforts since the 1970s have saved Californians over $65 billion, helped make household electricity bills 25 percent below the national average, and avoided at least 30 power plants.

California has achieved these efficiency benefits thanks to integrated policies that can be easily adopted elsewhere: advancing research and development of new efficient technologies; utility programs that help consumers use efficient technologies and processes to lower their bills; and minimum efficiency standards to ensure that consumers do not purchase inefficient appliances.

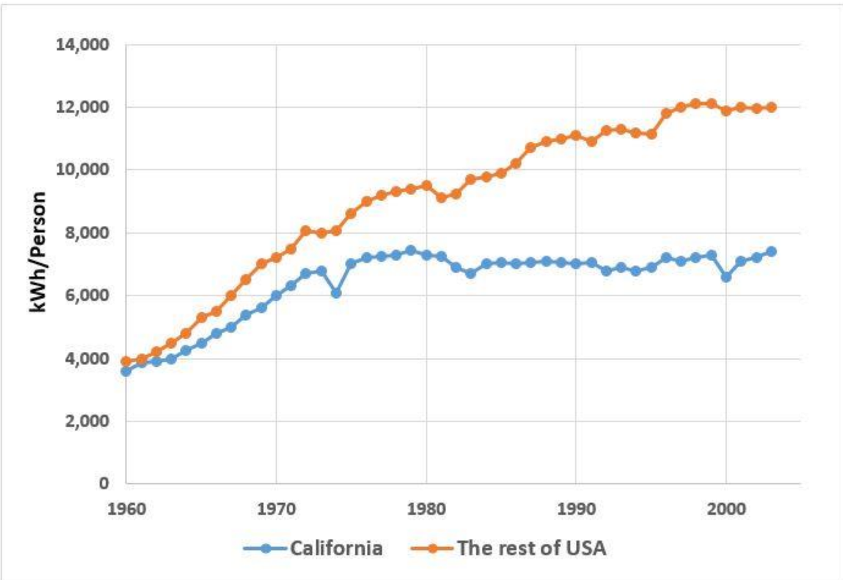


Figure 2: Per Capita Electricity Consumption: California vs. Rest of USA

[4] Source : US Energy Information Administration

Energy Management has been a subject of much interest. The International Organisation for Standardization (ISO) has prepared a framework for energy management. Launched in 2011, the ISO 50001 is a framework of requirements enabling organisations to:

i. develop a policy for more efficient use of energy;
ii. fix targets and objectives to meet the policy;
iii. use data to better understand and make decisions concerning energy use and consumption;
iv. measure the results;
v. review the effectiveness of the policy; and
vi. continually improve energy management.

2. Energy Management System

What is an Energy Management System?

The ISO 50001 standard defines the energy management system (EnMS) as follows: "*set of interrelated or interacting elements to establish an energy policy and energy objectives and processes and procedures to achieve those objectives*"

Essentially, an energy management system enables an organisation to achieve continual improvement of energy performance, energy efficiency, and energy conservation. The EnMS provides a formalised structure and systematic approach for ensuring that energy issues are addressed, and works to both control a company's significant energy aspects and achieve regulatory compliance.

Many practitioners have defined energy management as a process of managing the energy consumption in an organisation to ensure that energy has been efficiently used. It should cover all aspects of energy consumption, whether technical or non-technical. Perhaps not universally accepted are the objectives of energy management which might be categorised as resource conservation, climate protection and cost savings. Practitioners have found implementing a sustainable energy management system beneficial. In this book we will explore some of the following benefits that come with energy management:

i. systematic energy cost management;
ii. reducing operation and maintenance cost;
iii. increasing staff awareness on energy conservation and waste minimisation;
iv. developing organisation and staff knowledge;
v. setting up energy target & plan;
vi. setting up measurement & verification procedures;
vii. preparing energy reporting system; and
viii. supporting other quality systems.

2.1. Organising for Energy Management

Successful energy management requires that the delegation of functions and competencies extending from the top management to the worker be clearly defined. Let's start our discussion with those person(s) in top management who direct and control the organisation at the highest level. The top management must demonstrate its commitment to support the energy management system. Some actions by the top management might include:

i. establishing the energy policy;
ii. appointing a management representative and an energy management team;
iii. providing the resources needed to implement actions necessary to improve the energy performance of the organisation;
iv. identifying the scope and boundaries of the energy management system;
v. communicating the importance of energy management to everyone in the organisation;
vi. ensuring performance targets are established;
vii. ensuring that the energy performance indicators (EnPI) are relevant to the organisation;
viii. ensuring that results are measured and reported regularly; and
ix. conducting management reviews.

The management representative, who might well be the energy manager, plays a key role in the communication channels between the top management and the organisation. Depending on the size of the company, its overall management structure, in-house competencies, and other considerations, an effective organisational structure must be set up to drive energy efficiency efforts within the organisation. What is appropriate for one organisation may be less so for another.

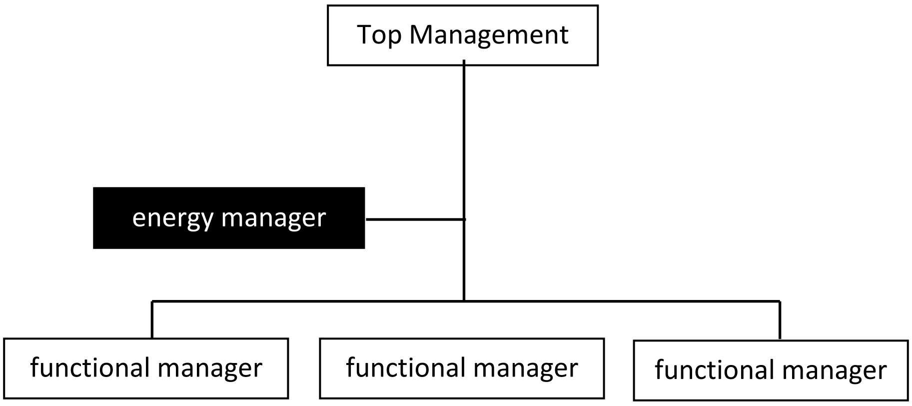


Figure 3: Organisation Structure

The management representative and the energy management team have found themselves located in between the top management and the second hierarchical level (typically, the functional managers). This energy manager supports the top management and keeps track of the energy management programme.

In some organisations the management representative and/or the energy manager found themselves reporting to the top management as one of the functional managers as shown in Figure 4. It is not uncommon to find the facilities manager and/or the chief engineer being selected to manage energy usage in an organisation. Facility management is a critical part of energy management, because energy costs might account for a significant proportion of the total operating costs. In all cases, the responsibilities for energy performance must be clearly defined within the organisational structure.

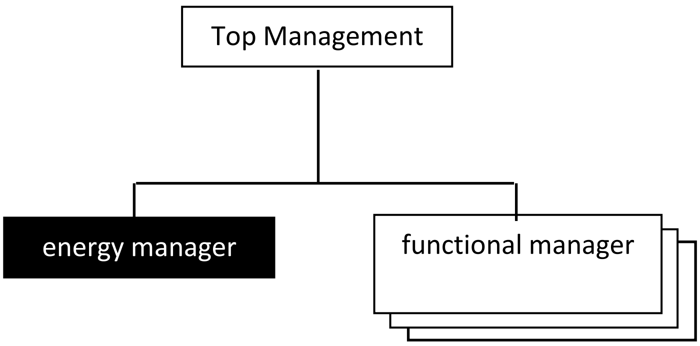


Figure 4: Energy Manager as a Functional Manager

2.2. Energy Manager and the Energy Management Team

So essentially, the task of the energy management team is to reduce energy costs in the factories and/or buildings without compromising work processes. A suitably qualified person should be appointed as the *Energy Manager.* His role will be to lead this team to achieve the goal of reducing energy costs. The team will deal with economical, ecological, risk-based and quality-based targets. The energy manager must drive energy management towards continual improvement and sustainability within an organisation (with a systematic and strategic approach).

Below is a list of some of the energy manager’s technical functions

i. assume the role as the in-house technical consultant on energy-efficient practices and new energy technologies; this includes the opportunities to consider alternative energy sources like solar power;
ii. setting performance standards for efficient operation and maintenance of equipment and facilities;
iii. identifying energy-efficiency measures after conducting energy audits;
iv. establishing an energy accounting system;
v. setting a benchmark against which energy-saving improvements can be measured;
vi. implementing energy conservation measures (ECMs);
vii. measuring and maintaining effectiveness of ECMs; and
viii. reviewing the facility’s operation and maintenance procedures for optimal energy management.

The energy manager is also expected to establish policies relating to the organisation’s use of energy. His roles might include:

i. fulfilling the energy policy established by top management;
ii. guiding energy management’s practices in adherence to industry codes;
iii. complying with regulatory activities, and recommending responses;
iv. representing the organisation in energy associations; and
v. preparing and submitting reports to the relevant government agencies.

In some organisations, the energy manager is involved in procuring energy from the utility service providers. The energy manager must then be familiar with the energy market and be expected to do the following:

i. forecast the facility's energy requirements and deciding on the contracted capacity;
ii. develop emergency plans for supply interruptions or shortages;
iii. prepare a budget for energy costs; and
iv. negotiate with utility service providers on energy contracts.

Besides procuring energy, the energy manager's duties may also include purchasing equipment to replace the existing ones which might have become obsolete and/or inefficient in energy consumption.

Finally, the energy manager has a public relations function too. Internally, it is important that a communications network be established so that feedback and suggestions might flow freely. All staff should be aware of the drive for energy efficiency and the benefits of these energy management efforts. The organisation should recognise and reward staff for completing energy projects successfully. Externally, the energy manager is the spokesperson in community and civic group meetings to create awareness of the organisation's achievement in managing its energy use and contribution to protecting the environment.

The energy manager should not have to do these alone. It is recommended that he recruits the help of representatives from different parts of the organisation to form an energy management team. So for a factory the team should have representatives from production, facilities, procurement, marketing, finance and even from the human resources department. The representative from production is most familiar with the major energy consuming processes. The inputs from this member of the team would be most helpful in identifying opportunities to implement energy efficiency projects. Similarly the representative for facility management can play an active role since the systems supporting the production processes also consume a significant amount of energy. As energy efficiency projects would typically require new investments in machinery and equipment, the team member from the finance office has an obvious role in analysing the financial aspects of a project. There would be financial objectives to be met just as there are energy targets. The timely availability of funds to support the project is critical to the success of any one project. To be sure that staff have the necessary competencies to support the energy efficiency drive, they should be adequately trained. The role of identifying training needs of the staff would fall squarely on the representative from the human resources department. In all, such a multi-disciplinary team stands a better chance to ensure the success of any energy efficiency drive by integrating people, place, processes and technology.

3. Energy Policy

The tasks to be undertaken by the energy management team shall be guided by the organisation's energy policy. Such a policy should be:

i. realistic, insofar as the organisation's energy use and consumption;
ii. sustainable, leading to continual improvement in energy performance;
iii. committed to ensure the availability of necessary resources to achieve objectives and targets;
iv. committed to the purchase and use of energy efficient products;
v. compliant with applicable legal requirements related to its energy use, consumption and efficiency;
vi. reviewed regularly to set energy objectives and targets; and
vii. documented and communicated at all levels within the organisation.

Here is an example of a policy statement:-

> *The company is committed to using energy in the most efficient, cost effective, and environmentally responsible manner possible. Towards this end, the company shall improve energy efficiency continuously by establishing and implementing effective energy management programs worldwide that support all operations and customer satisfaction while providing a safe and comfortable work environment.*

Take note, the organisation is making three important commitments in the energy policy. From the above, the organisation is committing to continual improvement in energy performance, committing to ensuring the availability of information and of necessary resources to achieve its energy objective and targets, and committing to complying with legal requirements and other requirements to which the organisation subscribes.

It is necessary for such a policy to be realistic and sustainable. It is not helpful to set too lofty a goal only to report sometime later that it is not sustainable. If the energy manager is to succeed in changing the behaviours of all personnel in the organisation, he should provide the relevant information and plan as early as possible. One recommendation is for him to express the support of top management for high-level goals in the initial communiqué.

Success in energy management is more likely when each representative of the various departments in the organisation sets the energy saving objectives. Such objectives must be consistent with the overall energy policy. Being the key person in formulating the energy policy, the energy manager must be prepared to answer a variety of questions from different areas of the company.

4. Energy Objectives and Energy Targets

4.1. Energy Accounting Process

It is a well-accepted management cliché that *what gets measured, gets done.* This wisdom cannot be over emphasized for the energy manager. The energy manager and his team must establish procedures for meter reading, monitoring, and tabulating facility energy use and profiles. Tracking utility bill data on a monthly basis provides a trend of the facility's energy performance and identifies instances of excessive usage. Utility bill analysis software can be used to track avoided costs. Although software is available as a tool for tracking energy use, for many energy managers, a simple spreadsheet is all that is needed.

Managing and controlling energy use in a large organisation may be difficult and at best only at a macro level. The organisation may be divided into smaller "energy accounting centres (EAC)" to facilitate the accounting process. The EAC, sometimes also called energy cost centres, could be defined i) by area, ii) by equipment, or iii) by system.

Commonly used indices are the energy performance indicator (EnPI) and the specific energy consumption (SEC) which are quantitative values or measures of energy performance. The organisation has to define this EnPI which could be expressed as a simple metric, a ratio of measured energy values or a more complex model. The measured (or absolute) energy values could be simply, kWh or GJ. This quantum figure indicates the energy consumed by an organisation. However, it provides little clue for what purpose was energy used and the efficiency of the energy used. The ratio of measured energy values provide a quantitative relationship between an output of performance, service, or goods and an input of energy. An example is kW/RT used in chilled water system. This relates the energy used to produce a unit of cooling (refrigeration ton, RT). A statistical model may also be used. This involves either a linear or non-linear regression. Sometimes the EnPI might be an engineering model based on computational simulations. Organisations might also have multiple EnPIs. At the management level, EnPIs could be energy performance of a production line or energy performance per m^2 for buildings. At the operational level, the EnPI selected might be the operational efficiency of a boiler.

With energy accounting, the energy manager could provide periodic reports to top management detailing the work accomplished, its cost-effectiveness, and plans for future work. For a successful energy-efficiency programme, continued monitoring and periodic re-auditing are necessary to ensure robustness. An energy accounting system that tracks consumption and costs on a continuing basis is essential. It provides energy use data needed to confirm savings from energy-efficiency projects.

As a start, the primary data source is utility bills. The energy manager might also find these other sources helpful:-

i. energy consumption records from sub-meters;
ii. temperature and relative humidity records;
iii. combustion efficiency, air-to-fuel ratio, and water quality tests;
iv. production records;
v. event recordings; and
vi. occupancy schedules and occupant activity levels.

4.2. Analysing Energy Data

Past bills from the utility company usually provide data on historical energy use. These are often monthly data and therefore should be analysed over several years. It is helpful to note the dates of meter readings so that energy use can be normalized for the number of days in a billing period. Sometimes, the consumption was estimated rather than measured. This might account for some fluctuations when incorrect estimations are adjusted in the next period. A base year should be established as a reference point. Although such data is helpful, data measured in shorter intervals paint a clearer picture of irregularities and is more suitable for closer examination.

It is useful to pause here and consider how this data might be used. Let's consider an example. Assuming a steel factory with a capacity of three (3) million tons per year produces round steel plates. The factory uses both electrical and thermal energy in the production process. The factory collects energy consumption data (electricity and thermal energy separately) on a monthly basis. The number of annual working hours is 7,000. In this case what should be the most appropriate energy performance indicator (EnPI) for this factory?

In the example the data collected includes production capacity, operating hours, electricity consumption as well as the thermal energy used in the production process. A useful EnPI might be energy consumed per ton of steel produced (MJ/ton). The data on electricity consumption, measured in kWh or MWh, may be converted into mega-joule (MJ) and combined with the thermal energy data, also measured in MJ. The number of operating hours per year may not be relevant here since the production duration and operating hours are not necessary the same.

4.3. Benchmarking and Establishing Energy Baseline

Benchmarking can be a useful first measure of a facility's energy efficiency. The normalized energy consumption by a facility may be compared to one that is similar. This is a powerful tool for performance assessment and a logical evolution of avenues for improvement. Benchmarking can be done internally using historical and trend analysis. It is also done externally comparing the facility's performance against similar facilities. There are several methods of benchmarking.

i. based on past performance; a comparison of current against historical performance;
ii. based on industry average; a comparison against the recognised average performance of a peer group;
iii. based on the best in class; a comparison against the best in the industry and not the average; and
iv. based on best practices; a qualitative comparison against certain established practices considered to be the best in the industry

It is important to set a target for the improvement expected from an energy efficiency project. The first step would be to collect data, both energy consumption data and also data on the factors relating to the component using the energy. Data on energy consumption should include all energy sources. Typically, most facilities will use a combination of electricity, gas and diesel as energy supply. Both electricity and gas supply are normally metered only when consumed.

When accounting for consumption of diesel, the calculation gets more complex since the amount of diesel supplied to the plant may not equal the amount that was consumed. The energy manager must understand the utility rates that apply to each facility since most energy management activities are dictated by economics.

Data on the factors relating to the component using the energy might include quantity of goods produced, building occupancy, and operating hours. The next step would be to establish a relationship between the energy input and the related factors. The analysis of a chilled water plant is a good example. Figure 5 shows the chilled water system efficiency plotted against the cooling load. The chilled water system efficiency is measured as kW/RT which is the EnPI or SEC. The cooling load is measured as RT (refrigeration ton) which is the production level.

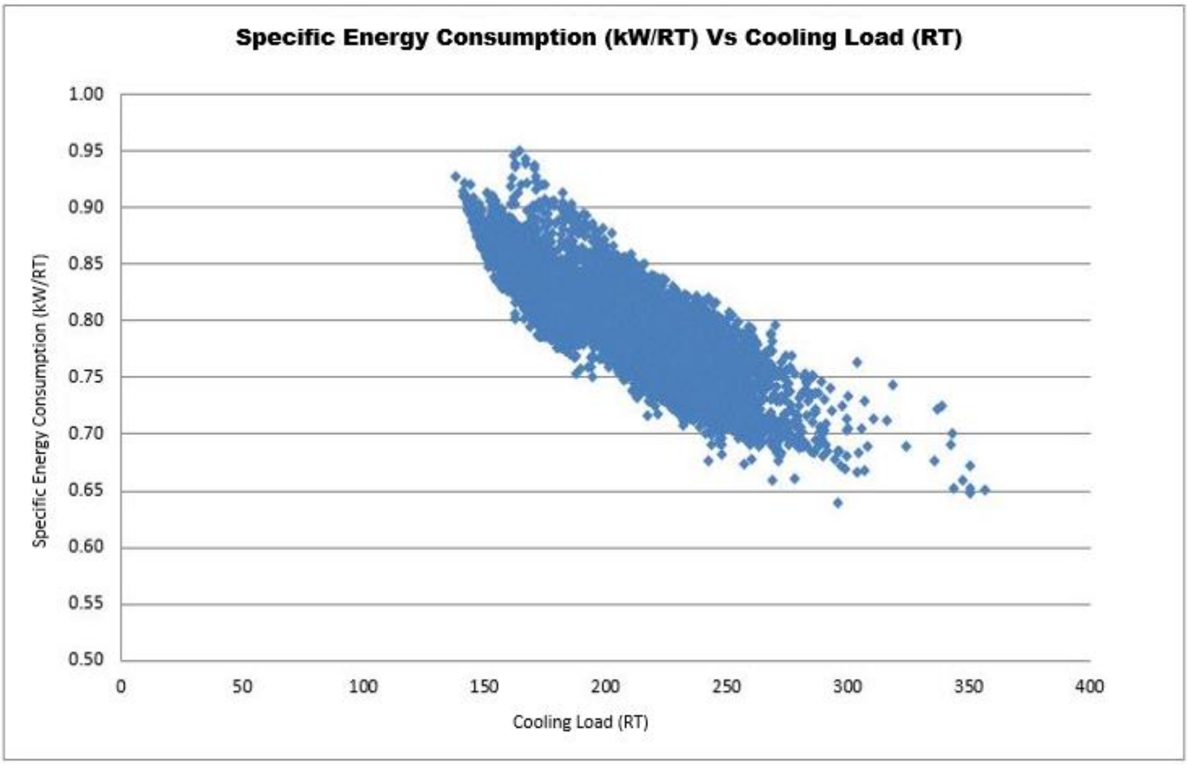


Figure 5: Chilled-Water Plant's Specific Energy Consumption vs Cooling Load

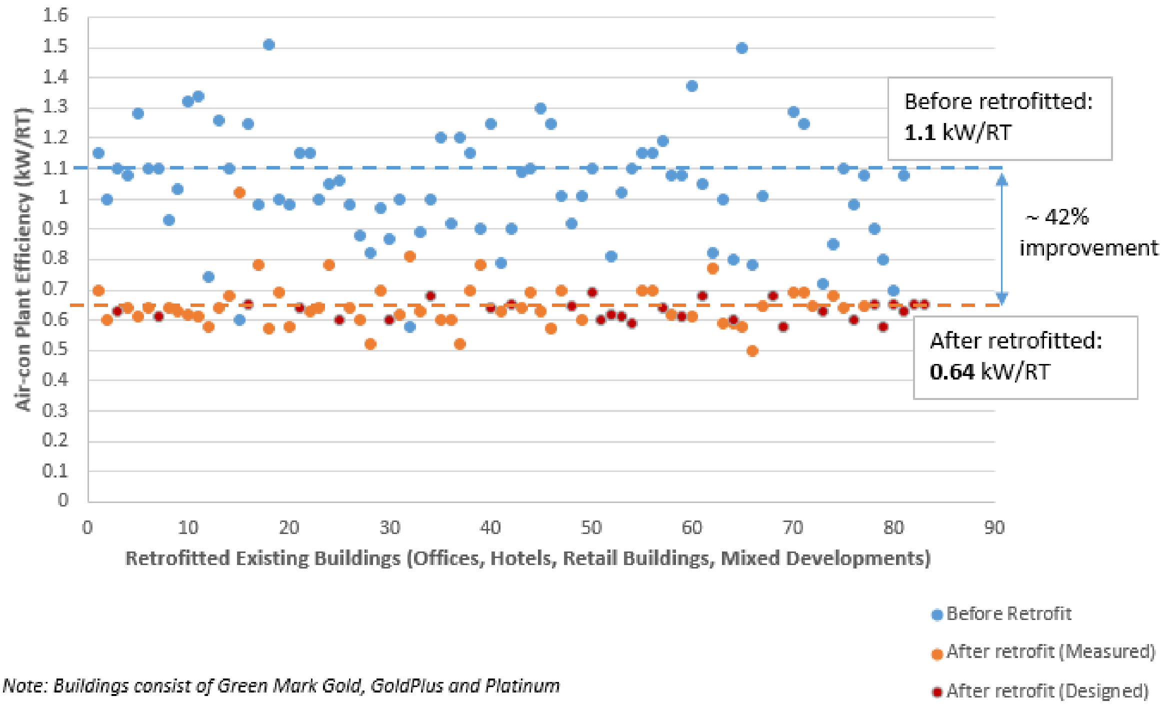
The plot shows the relationship between the specific energy consumption (SEC) against the production level of a chilled water system. Establishing this relationship helps the energy management team to monitor energy efficiency at each production level. We note that the higher the SEC, the more energy is consumed per unit of production.

Another useful relationship is the SEC vs time. This helps the energy management team to understand the nature of energy consumption according to the season. It indicates the time of the year where the best performance and lowest performance have occurred. If twenty four (24) months of data can be obtained, energy consumption performance can be compared on a year-on-year basis.

Next, we find out *lowest* and *average* energy consumption rate. In this case, the average SEC is almost 0.8 kW/RT when 220 RT of cooling is produced. The lowest SEC is recorded at 0.64 kW/RT when the chiller is running at 300 RT. This is the most efficient operating point. The energy manager could set the *average SEC* as baseline and set the *lowest SEC* as the savings target. In other words, the benchmark for this chilled water system is set at 0.8 kW/RT and a target has been set to achieve a plant efficiency of 0.64 kW/RT.

Benchmarking is also done at an industry wide level. In 2014, Singapore's Building and Construction Authority (BCA) started publishing an annual report[5] to show a snapshot of where commercial buildings stood in terms of energy performance. One study found that the combined total electricity consumption in 83 buildings which had undergone energy retrofitting saved about S$41 million per year. The EnPI improved from 323 kWh/m^2/year to 273 kWh/m^2/year. The efficiency of the air-conditioning plants in these buildings improved by an average of 42% from 1.1 kW/RT to 0.64 kW/RT (kW per refrigeration ton).

Building owners and operators are able to compare their building's chilled water system's SEC to similar buildings to determine if further engineering study and analysis are likely to produce significant energy savings. Conducting an energy audit will establish the SEC of the chilled water system.



Source : BCA Building Energy Benchmarking Report 2014

Figure 6: Improved Performance of Air-conditioning Plant

[5] Source : BCA Building Energy Benchmarking Report 2014

4.4. Energy Audits

An energy audit can be simply defined as a process to evaluate where a building or plant uses energy and to identify opportunities to reduce consumption. The audit process may be broken down into these steps:

i. Collect and analyse historical energy consumption profile
   a) Review more than one year of energy bills; (preferably three years);
   b) Make a note of all past changes in electricity tariff;
   c) Look out for irregularities in the consumption pattern; and
   d) Derive target goals for energy, demand and cost indices.

ii. Study the facility / building and its operational characteristics
   a) Understand the types of mechanical and electrical systems in use;
   b) Conduct a walk-through survey to become familiar with the facility's construction, equipment, operation, and maintenance;
   c) Conduct interview with owner/operator and if possible, the occupants to learn of any dissatisfaction with the mechanical or electrical services; for example if the air-conditioning is too cold; and
   d) Identify the on-going upgrading, breakdown and/or repairs to existing systems and equipment.

iii. Identify opportunities to modify the equipment or its operations to reduce energy use
   a) Identify low-cost/no-cost changes to maintenance procedures that help reduce energy use
   b) Identify inefficient /obsolete equipment for potential retrofit opportunities
   c) Identify training needs for operating staff
   d) Make a quick estimate of the breakdown of energy consumption for major equipment / services

iv. Do a feasibility study covering both technical and economic analysis of potential energy retrofit.

a) For each practical measure, perform a costs and benefits analysis;
b) study effects on the facility / building operations and maintenance costs; and
c) Prepare a financial evaluation over the estimated economic lifespan of the energy efficiency measure.

v. Prepare a priority list

a) List all possible energy savings measures;
b) Identify those measures that are practical to implement as high priority;
c) Make preliminary estimates of costs and savings; and
d) Recommend the measure that has best return on investment to be implemented first.

vi. Prepare a Report

a) Describe the building / facility and the operating requirements, and identify the systems that consume significant amounts of energy;
b) State the assumptions of each energy efficiency measure and how the savings might be derived;
c) Review list of practical measures with the top management;
d) Recommend the measures for implementation starting from those at the top of priority list. Prioritize modifications in recommended order of implementation; and
e) Prepare a measurement and verification methodology.

Depending on the type of information that can be expected and an indication of the level of confidence in the results, there are three categories or levels of energy audits.

<u>Level I: Walk-Through Audit</u>

By its name, this assessment makes a brief survey of the facility or building. The energy auditor looks at a facility's current energy cost and efficiency by analysing energy bills. This level of audit depends on the experience of the auditor and the client's specifications. It is conducted to provide a gauge of the energy savings potential of a facility. One outcome is a recommendation for low-cost measures to improve energy efficiency. This might include identifying capital improvements that require further considerations. The auditor is also expected to estimate the costs of the recommended measures and the potential savings the client may expect when the measures are implemented. A Level I audit can be used to develop a priority list for a Level II or III audit.

Level II: Standard Audit (Energy Survey and Analysis)

Developing from a Level I audit, the audit team will need to analyse the energy consumption in greater detail. A breakdown of the energy consumption in the facility or building will help prioritise and identify which energy conservation measures (ECMs) should be studied. Working with the client, the auditor should also study the impact of all the ECMs on operation and maintenance procedures. The estimated costs and potential savings of all ECMs shall be listed for comparison. The audit should also identify potential capital-intensive improvements that will require more thorough data collection and analysis. For most facilities and buildings, this level of energy audit should be the minimum that should be performed in an energy management programme.

Level III: Detailed Analysis of Capital-Intensive Modifications

This focuses on potential capital-intensive projects identified during the Level II audit and involves extensive data gathering and engineering analysis. As it is expected to be an investment grade audit, detailed information on project cost and savings are gathered. It is not unusual to see the deployment of high accuracy instruments and data loggers to continually measure, at 1 minute intervals, energy use and efficiency over a period of 1 to 2 months.

5. Energy Efficiency Improvement Plan

5.1. Energy Efficiency Measures

There are numerous ways to conserve energy. The first thing to do is to reduce wastage by simply turning off equipment when they are not needed. While the occupants should be expected to exercise such discretionary operations, sometimes technologies help in this endeavour. Here are two examples which are quite common in modern buildings:

i. Turning off artificial lighting using motion sensors and light-sensitive controls; and
ii. Reducing ventilation rates during periods of low occupancy using CO_2 sensor

Purchase Lower-Cost Energy

The energy manager must understand the utility rates that apply to his facility. One effective way to reduce energy cost would be to purchase lower cost energy. The energy manager should work with utility providers to find the most favourable rates for their buildings. Electricity rates can be complex as different rates may apply at different times of the day, or if interruptible service had been negotiated. The energy manager should explore these options:

i. Negotiating for lower-cost utility rates
ii. Implementing power factor correction measures to avoid penalties
iii. Shifting part of the energy use to off-peak periods
iv. Cogeneration
v. Lower-cost fuels

Optimise Energy Systems Operation

One of the more effective steps that the energy management team can take to reduce energy use and energy costs is to continually optimise the system performance of the plant. This should be an ongoing process combining training, preventive maintenance and system adjustments. Below are some recommended actions for optimising performance:

i. Establishing a preventive maintenance program;
ii. Training operating engineers and technicians;
iii. Tracking the occupancy patterns and adjusting set points;
iv. Cleaning or replacing filters; and
v. Regular flushing of pipes and ducts.

Purchase Efficient Replacement Systems

The energy management team must constantly watch for opportunities to replace equipment or systems that are less efficient. Such replacement must be evaluated objectively. The energy manager need not wait till the less efficient equipment is near its end-of-life before considering replacing it. The optimum time for replacement would be when the benefits outweigh the replacement costs. Here are examples of systems that are commonly replaced:

i. Air-conditioning systems;
ii. Artificial lighting systems;
iii. Hot water service system;
iv. Pumps and fans; and
v. Motors.

Optimising More Complex Systems

For more complex systems, it is recommended that additional strategies be considered. A strong team of facilities personnel and perhaps even external consultants may be deployed to do regular commissioning. The objective is to optimise the performance of the systems / services as the operating conditions evolve with changing parameters. Such works might include retro-commissioning for systems that were not previously commissioned and on-going commissioning of systems even after the facility is occupied and well into the commencement of operations.

Some important measures typically implemented include:

i. Chiller sequencing and optimisation;
ii. Pump controls optimisation;
iii. Fan controls optimisation;

iv. Boiler controls optimisation;
v. Setting up monitoring and reporting of KPIs (key performance indicators); and
vi. Specialized training for operating personnel in optimisation strategies.

5.2. Identifying Energy-Efficiency Measures

The energy management team can evaluate the end-use energy profile to identify energy-efficiency measures (EEMs). Below are 3 common areas/equipment where energy efficiency measures can be identified.

Table 1-1: Potential areas/equipment where energy efficiency measures can be identified

Central Chilled Water System	
i.	Chillers
ii.	Cooling towers
iii.	Pumps
iv.	Condensing units
v.	Piping insulation
vi.	Air-handling units
vii.	Filters
viii.	Air leakages

Table 1-2: Potential areas/equipment where energy efficiency measures can be identified

Artificial Lighting	
i.	Lamps
ii.	Ballasts
iii.	Light switching options

Table 1-3: Potential areas/equipment where energy efficiency measures can be identified

Boiler Plant & Hot Water Service	
i.	Boilers
ii.	Steam distribution systems
iii.	Condensate systems
iv.	Steam traps
v.	Energy recovery

The energy management team should be careful to allow for system interaction of various energy efficiency measures so that the savings can be accurately calculated. For example, by switching to energy-efficient T5 lighting, the obvious savings will be derived from the power savings from say, 15 W/m^2 when using incandescent bulbs to 8 W/m^2 with T5 lamps. The impact on the chilled water system is, however, less obvious. One would expect that the reduced cooling load will result in a proportional amount of energy savings. However, several other factors come into play including the poor part load performance of the chilled water system. A good practice is to routinely evaluate the energy performance of projects implemented in the past to ensure that equipment are in good working order and target savings are achieved. The energy manager should also review such measures to adjust to changes in technology, building use, and/or energy cost.

There are other factors that influence the choice of energy efficiency projects. Some important considerations in this process are as follows:

i. Alignment with corporate goals;
ii. Impact to normal operations;
iii. Installation requirements;
iv. Life-span of the equipment;
v. Maintenance costs; and
vi. Energy measurement and verification requirements.

5.3. Evaluating Energy-Efficiency Measures

The energy management team has to prioritise the energy efficiency measures that would be implemented. There are three broad considerations in making this appraisal.

i. Technical evaluation
   a) Amount of energy saving
      - total savings (energy, cost avoidance)
      - initial cost (required investment)
      - confidence in predicted savings
      - rate of increase in energy costs
      - maintenance complications

   b) Technology risk
      - increased maintenance costs
      - potential obsolescence

   c) Implementation period
      - resources available
      - effect on indoor environment

   d) Impact to normal operation
      - safety
      - comfort

ii. Financial evaluation, to prove that energy savings can improve profitability
      - rate of return
      - simple payback period
      - net present value (NPV)
      - internal rate of return (IRR)
      - life-cycle cost

iii. Other considerations
      - cost avoidance
      - improved system reliability

- improved productivity
- utility rate structure

After an energy audit is conducted, the energy manager would be aware of the major energy consuming systems and how much energy each system consumes. To illustrate, consider an office building whose energy consumption is found to be in the proportion shown in figure 7 below. The chilled water system accounted for about 47% of the total energy consumed. This is significantly more than the 3% consumed by lifts and escalators.

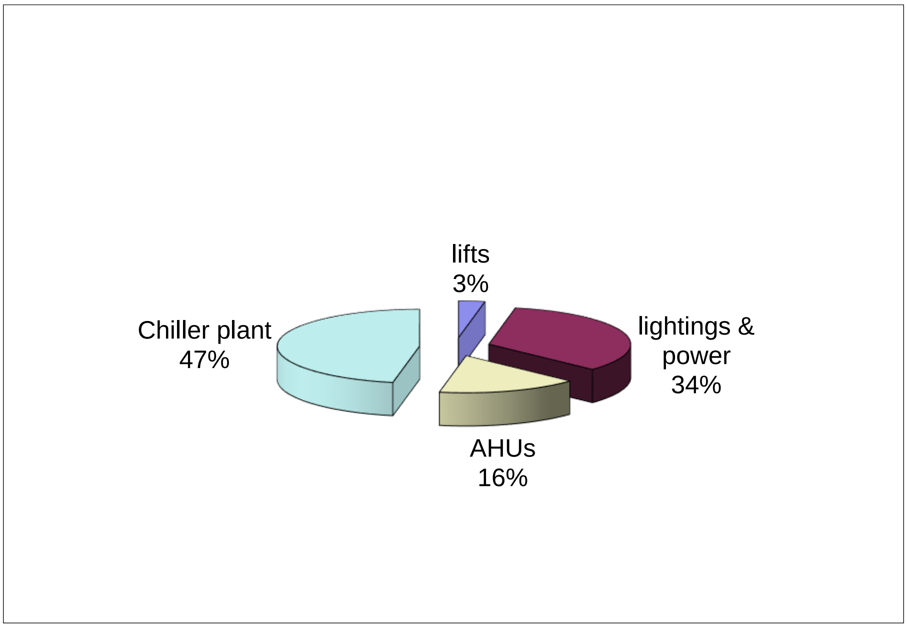


Figure 7: Energy consumption in a typical office building

The energy manager should first focus on the major energy consuming systems like the chilled water system to explore how to make it more efficient. If he finds an energy efficiency project that will save 10% of the energy consumed by the chilled water system, it would mean the project will save 4.7% of the total energy consumed by the whole building. Intuitively, this is more productive than trying to save 50% of the energy consumed by the lifts which equates to just 1.5%.

There is, however, a technology risk that the energy manager has to consider. Energy saving solutions are usually innovative and new to the energy manager. The energy manager has to satisfy himself that the solution will work and deliver the energy savings. The energy manager might have to overcome the organisation’s natural resistance to change. However, this is not the same as waiting till a technology has been so widely tried and tested before deciding to change. The energy manager should keep an open mind and actively learn from other early adopters of the energy saving solution. The role of the energy manager should include managing the risk of adopting the new technologies.

Let's consider the use of LED lamps for artificial lightings. This technology challenged the use of the traditional incandescent lamps and fluorescent lamps but the energy savings potential is substantial. Not so long ago, many users experienced problems with the lamps' ballasts/drivers. Some organisations will choose the route of doing nothing and wait for the technology to improve. However, this would mean missing out on opportunities to save energy. The energy manager could proceed in measured steps. He could perhaps identify a smaller area where he could install these LED lamps as a pilot test. If the trial delivers the promised energy savings, he could decide to adopt the technology on a wider scale. Should the result of the pilot implementation fall short of the potential savings, the energy manager could learn from that experience and understand the reasons of what went wrong. He could make adjustments to the projects and repeat the trial or postpone the adoption of this technology. LED lamps have since made significant inroads and found many adopters of this technology and is fast becoming the default choice for artificial lighting.

The energy manager could also consider using a new technology while having the existing technology as a back-up. An example is found in hotels where the hot water service is traditionally generated by heaters fired by fossil fuels. When heat pumps were introduced, many engineers retained the existing gas-fired heaters as back up heaters. As good experiences are gradually gained, heat pumps are now common place.

The energy manager must then consider how the energy saving solution might be implemented in his plant. The ideal situation would be to choose a period when the facilities can be shutdown to implement the energy saving solution. This might be over a period of hours during nightfall, a period of days over a weekend or a public holiday. Some plants are also known to schedule a shutdown period for maintenance works, upgrading works and/or improvement works such as energy saving projects.

As would be expected, the organisation would permit little, if any, impact to its normal operation. This consideration is especially acute for production or manufacturing facilities. Commercial buildings and hotels are usually able to minimise the impact that any energy saving project will have on the organisation's normal operations. For example, hotels can close some floors for implementation of energy saving LED lamps while maintaining business-as-usual operations on other floors.

Very often, the energy consumption is over-estimated and the predicted savings are not achieved. When an organisation previously suffered such a bad experience, it becomes extra guarded when deciding on another energy savings proposal. The energy manager must therefore understand the success of others who have worked with the same measures. This means studying the documented performance of the measures and evaluate if those success factors are present in his proposed application. To do this, the energy management team must have personnel with strong technical expertise. This will raise the confidence level of the predicted savings and reduce risks of bad experiences. Also, it cannot be over-emphasized that top management attention and commitment to the project is a critical factor in the success of an energy project.

5.4. Implementing Energy-Efficiency Measures

Having identified and evaluated several energy efficiency measures, the energy manager must present these to the organisation's top management. At this stage the energy manager must be sure that on its own each measure is technically and financially viable. Every organisation, after all, has limited funds that must be used in an effective manner. The energy manager must understand that energy efficiency projects are competing with other projects for the same limited funds.

A successful plan must be easily understood by the top management. The report on each energy efficiency measure should therefore include the following:

a) present condition of the system or equipment being studied;
b) the recommended action – to replace or to upgrade;
c) indication of the person(s) who should be responsible for the implementation ;
d) the appropriate documentation or follow-up required;
e) a measurement and verification plan ;
f) risk of failure;
g) impact on the workplace or production processes;
h) staff effort and training required;
i) economic analysis (including payback, life cycle cost analysis);
j) other benefits such as improved system reliability, improved productivity; and
k) schedule for implementation.

Once the approval is given, the energy manager and his team must get on with the action plan. Some measures may involve external parties, such as consultants, to assist in the preparation of drawings, and technical specifications. A suitable contractor is then selected through a competitive bidding process. The energy management team would then supervise the implementation works and where necessary get the appropriate staff to be trained to operate the new measures.

6. Monitoring, Measurement and Analysis

6.1. Key Performance Indicators

The next step is to continually monitor the progress of the implementation of the energy efficiency measures. Procedures need to be established to record the energy consumption for each energy system and in such frequency that is practical. Besides the utility bills, sub-metering may be needed to record the relevant information on energy use. Although digital metering devices that read and transmit the data to a control room will be helpful, the costs of these devices are not insignificant. There is a need to justify the installation of such meters making sure the benefits outweigh the costs. Analogue meters that require regular readings by the technician will do as well especially if only hourly information is required.

The energy management team should review the energy use profile regularly. If the data indicates a trend of deviation from an expected performance profile, i.e. in the wrong direction, the energy management team can investigate the deviation. Sometimes the data are corrupted by uncalibrated instruments, changes in the operating routine or even component failure. The energy management team should act to rectify these irregularities immediately.

6.2. Tracking Performance

The energy management team must begin to track the performance with clear KPIs (key performance indicators). To be proactive, the team should monitor the energy consumption on a daily basis. The aim of tracking the performance is to spot a trend going off track and taking remedial actions as quickly as possible. This discrepancy will then have limited impact on the target savings. The implementation of such monitoring of performance requires a robust measurement and verification plan. Every energy consuming system must have set points for key parameters such as the specific energy consumption (SEC), temperature and flowrate. Should the SEC rise above the set point by a pre-determined value, an alarm should be raised. The energy management team should then investigate the cause of the irregularities and correct any operational discrepancy. The standard operating procedures (SOPs) must support this strategy so that troubleshooting may be done by the operation staff.

6.3. Developing New Goals

The baseline model is a three-step process:

i. Pick a period that most closely reflects the current consumption profile;
ii. Create the baseline model using the past years' utility bills; and
iii. Identify a target model to track the energy performance.

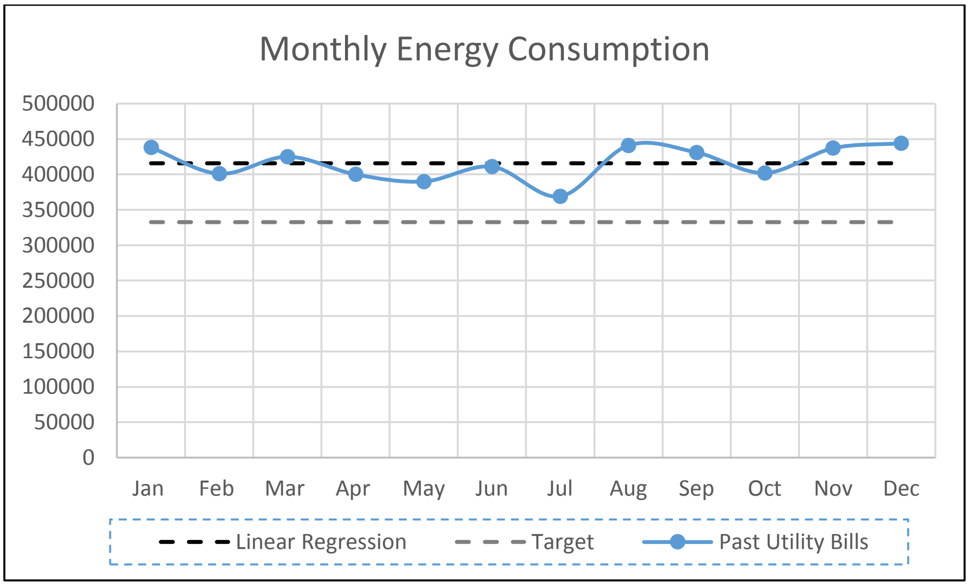


Figure 8: Past consumption data being used for establishing a base line

Figure 8 shows the utility bills of the past three years being used as the baseline model of a building's energy consumption. This is called a whole-building measurement and verification versus time. Through linear regression, utility bills are normalized to their daily average values. Repeated regression is done until the regression data represents the best fit to the utility bill data.

6.4. Reporting

It is recommended that reports on energy performance be made on a quarterly basis. The energy management team should also report to the top management how the adopted energy efficiency measures affect the operating and maintenance costs. Figure 9 shows the actual energy consumption for six months being plotted in comparison to the target level of consumption.

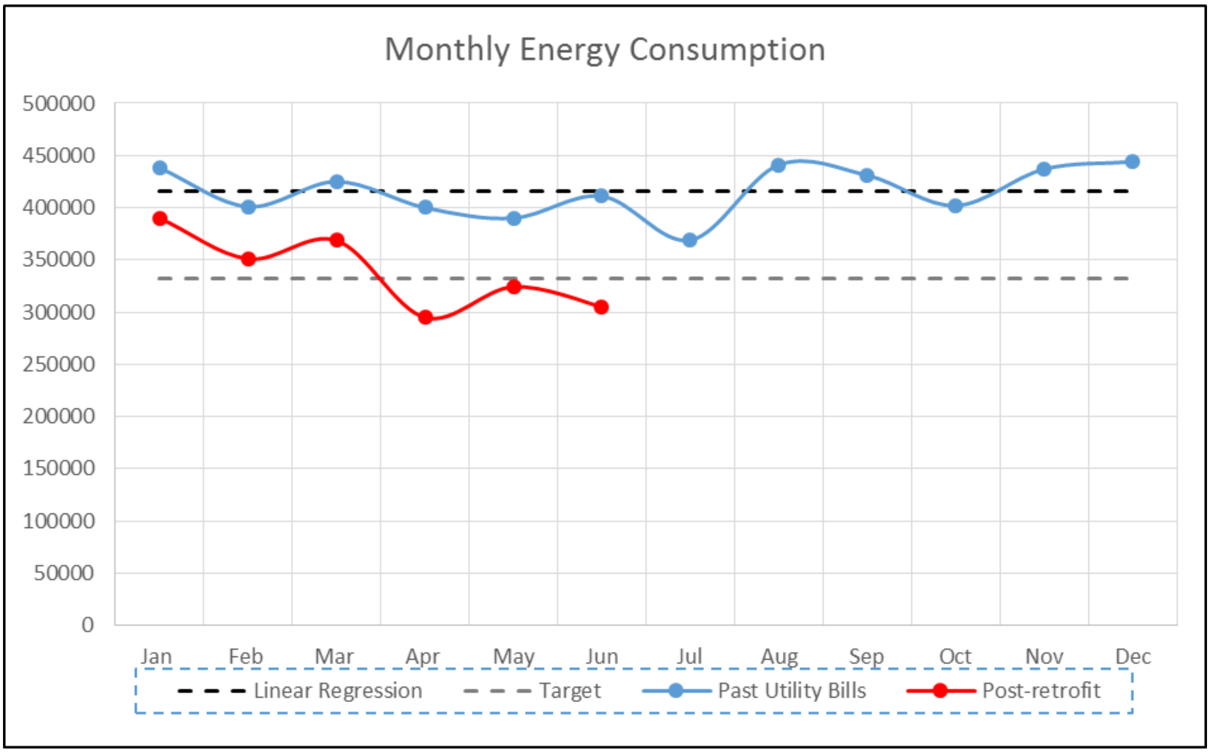


Figure 9: Comparison of monthly energy comparison

When developing presentation materials to document energy performance, make sure that the report content shows performance as related to key performance indicators (KPIs) used by the organisation. Reports should be pertinent to the audience. Whereas a report to the company's administration would show how the energy management program affects operating and maintenance costs, a separate report to the operations staff should show how their daily decisions and actions change daily load profiles.

7. Continual Improvements

7.1. Communications

The commitment from all stakeholders in the organisation is necessary to successfully implement energy management. This includes executives in top management to staff at the operational level. Stakeholders must see the benefits that energy efficiency can bring to the business of the organisation. Communication channels within the organisation must facilitate the free flow of feedbacks and suggestions. One measure of success of getting commitment is how quickly the energy management activities will become second nature to the organisation. One effective way is to recognise and reward staff who have participated in energy efficiency projects. In this manner, other staff in the organisation might be encouraged to do their part in supporting the drive for energy efficiency.

Communication is an integral part of an effective energy management programme.

i. The energy manager should tailor the content of the message to each specific audience in the organisation. An effective communication strategy may include:-
    a) producing posters and leaflets with energy-saving tips or reminders;
    b) circulating a regular newsletter;
    c) meeting regularly with operations staff for training and feedback; such meetings can be held in group discussions or with individuals; and
    d) reporting regularly to management and operations staff; this promotes accountability and persistence of performance.

7.2. Documentation

Documentation is an important part of the energy management system. The extent of documentation can vary according to the size and the type of activities of the organisation, the complexity of the process, the quantity of energy use and the competence of the personnel.

The following elements of the energy management system should be documented:

i. The energy policy;
ii. The scope and boundaries of the energy management system;
iii. The energy objectives, targets and action plans; and
iv. Documents including those required for compliance to standards, legal and regulatory requirements.

There should also be procedures for documents to be periodically reviewed, updated, and revised. Although documents should be made accessible at the point of use, appropriate measures must be put in place to control the distribution of the documents.

7.3. Management Review

There should be regular reviews by the top management to ensure that:

i. the energy management system (EnMS) is appropriate for the organisation;
ii. the EnMS meets the organisation's requirements; and
iii. the energy performance is achieved and can be continually improved.

After the management review, the energy policy may be changed or adjusted to reflect any changes in legal requirement or other requirements under which the organisation operates in. Energy objectives, targets, and performance indicators (EnPI) might also be changed depending on the extent to which the organisation met the objectives in energy performance in the preceding periods. Accordingly, the management review might see the re-prioritisation of resources being allocated.

Hence a management review shall include updates on the following:

i. whether follow-up actions from the previous review are taken up;
ii. whether there is compliance with existing and new legal requirements;
iii. whether energy performance indicators (EnPI) are appropriate;
iv. whether energy objectives and targets are met and if not, what are the deviations;
v. whether corrective actions are progressively taken;
vi. whether the audit of the energy management system showed any non-conformities; and
vii. whether the projected energy performance is in line with the organisation's energy policy.

The output from the management review shall include any decisions or actions related to the following changes:

i. energy performance of the organisation;
ii. objectives, targets or other elements of the energy management system;
iii. energy performance indicators (EnPIs);
iv. allocation of resources; and
v. energy policy.

8. Other Energy Management Systems

8.1. ISO 50001

The standard is a best practice checklist, based on feedback from many users. It uses a systematic PDCA (Plan-Do-Check-Act) approach towards change and improvement. Since it has a similar structure to the quality and environment management standards ISO 9001 and ISO14001, it can be integrated with them quite easily. In the context of energy management, various steps for the PDCA approach are:

i. PLAN

Conduct the energy review and establish the baseline, energy performance indicators, objectives, targets and action plans necessary to deliver results in accordance with opportunities to improve energy performance and the organisation's energy policy.

ii. DO:

Implement the energy management action plans

iii. CHECK

Monitor and measure processes and the key characteristics of its operations that determine energy performance against the energy policy and objectives and report the results.

iv. ACT

Take actions to continually improve energy performance and the energy management system.

This Plan-Do-Check-Act (PDCA) continual improvement framework incorporates energy management into everyday organisation practices.

ISO 50001 included a clause (4.4.2) to require the organisation to identify, implement, and have access to the applicable legal requirements and other requirements. The energy management team must then determine how these requirements apply to its energy use, consumption and efficiency. The organisation must ensure that these legal requirements are considered in establishing, implementing and maintaining the energy management system.

Below are some examples of legal requirements in the context of energy management:

i. International legal requirements such as the Montreal protocol
ii. Local by-laws such as the Electricity Act, Energy Market Authority of Singapore Act; and
iii. Building standards and codes of practice.

Other requirements refers to non-regulatory guidelines, public commitment of the organisation or its parent organisation or voluntary principles or code of practice; … etc.

One common example of non-compliance of local standards is the use of electric re-heaters in air conditioning system. The Singapore Standards SS553[6] specifically stipulates that the control of the indoor environment by reheating the air shall not be allowed except for energy source from site-recovered energy (including condenser heat) or site solar heat. However, many air conditioned spaces especially where humidity control is critical, electric re-heaters are found to be in use inside the air ducts or as part of air conditioning equipment. This practice will therefore not comply with the ISO 50001 requirement.

While this clause (4.4.2) is featured in the energy planning process as part of the planning phase, ISO 50001 has a related clause (4.6.2) to evaluate compliance with legal requirements and other requirements to which the organization subscribes related to its energy use and consumption. This is done in the checking phase.

In ISO 50001, the energy review is a 3-step process which involves:

i. Analysing energy use and consumption
ii. Identifying areas of significant energy use and consumption
iii. Identifying opportunities for improving energy performance

[6] Singapore Standard SS553:2009 Code of Practice for air-conditioning and mechanical ventilation in buildings

This energy review should be carried out by competent people from within the organisation; although the participation of subcontractors is permitted. It is based on information and data such as the records of past and present energy use and consumption. Other inputs include the relevant variables affecting the significant energy uses and the energy performance of the energy use. The energy review would shape the energy management system, and as a document, the energy review must be updated whenever necessary.

The reliability of the sources of information cannot be over emphasized. Very often energy suppliers' past invoices are used. Care must be exercised as invoices are sometimes based on consumption estimate. This can be very different from the real consumption figures. Besides historic meter readings, staffing levels, working hours and patterns are important sources of information. Above all, the facilities, equipment, processes and work practices must be scrutinised.

The outcome of the energy review is the establishment of the following

i. Energy baseline
ii. Energy Performance Indicators (EnPI)
iii. Objectives
iv. Targets
v. Action Plans

It is useful to note that it is not the intention of the ISO 50001 to prescribe specific performance criteria with respect to energy use. For example, there are neither requirements on energy efficiency improvements nor provisions on budget and investment. ISO 50001 is applicable to any organisation that wants to ensure that it conforms to its stated energy policy and wishing to demonstrate this to others, such conformity being confirmed either by means of self-evaluation and self-declaration of conformity, or by certification of the energy management system by an external organisation.

8.2. ASEAN Energy Management Scheme (AEMAS)

The AEMAS is a regional cooperation to promote energy efficiency. The objective is to establish a regional scheme with mutual recognition amongst the ten South East Asian countries. AEMAS is based on ISO 50001 with additional features to address what it sees as two major obstacles in energy management. The developers of AEMAS noted that energy managers lack managerial skills as most training for energy managers focused on technical aspects. It also found that end-users are not motivated to invest in energy efficiency. Apart from the industries that are energy intensive, cost savings is not a strong driver. The training curriculum therefore focuses exclusively on managerial aspects on how to establish and manage the energy management system.

Energy managers certified by AEMAS have improved cross-border employment opportunities besides having improved professional standing and enhanced career development paths. Organisations certified by AEMAS can look to these benefits

i. facilitated compliance with international standards including ISO 50001;
ii. better opportunities for international business;
iii. better recognition in ASEAN;
iv. enhanced competitiveness; and
v. verified achievements and savings.

9. Public Policy & Practice

9.1. Public Sector Taking the Lead in Environmental Sustainability (PSTLES)

The public sector is committed to take the lead in environmental sustainability and adopt a long-term view in resource efficiency. Under the *Public Sector Taking the Lead in Environmental Sustainability* (PSTLES) initiative introduced in 2006, public sector agencies have been encouraged to put in place environmental sustainability measures that include energy efficiency, water efficiency and recycling.

In 2014, the PSTLES initiative was enhanced to encourage agencies to focus attention on sustainability outcomes and to put in place organisational processes to manage resource use. Some of the key enhancements include requiring each Ministry to appoint a Sustainability Manager, set sustainability targets to be attained by 2020 and develop a resource management plan to meet the targets.

Under this initiative the public sector has set these targets:

<u>Resource Management</u>

i. Sustainability Target:

a) All government ministries are to set aggregated improvement targets for energy, water and waste to be achieved by the year 2020. Agencies that have been identified with potential for solar deployment shall set a renewable target for the total solar PV capacity to be installed by FY2020.

b) Resource Management Plans:
All government ministries are to submit Resource Management Plans (RMPs) that document their sustainability targets and the resource conservation measures to achieve these targets. All owners of public sector premises are to submit information on their annual resource consumption.

c) Appointment of a Sustainability Manager:

Each government ministry is to appoint a Sustainability Manager (SM) to oversee efforts within the Ministry and its Statutory Boards, including overseeing the implementation of the Resource Management Plans.

ii. Green Buildings

a) New and existing buildings:

New public sector buildings with more than 5,000 m^2 air-conditioned floor area, including buildings with development cost fully or partly funded by the public sector (e.g. new universities and hospitals) must attain the Green Mark Platinum rating.

All existing public sector buildings with more than 10,000 m^2 air-conditioned floor areas must attain the Green Mark Gold^{Plus} rating by the year 2020. Those buildings with more than 5,000 m^2 gross floor areas but less than 10,000 m^2 air-conditioned floor areas must attain the Green Mark Gold rating by the year 2020.

b) Office Premises:

All new public sector office premises or those that undergo major renovation are to achieve at least the Gold rating under the Green Mark for Office Interiors scheme. Office premises that do not fall under the above category are to retain the Eco-office Green Office Label till their next office renovation.

c) Tenanted Office Premises:

Public sector agencies that lease office spaces are to lease from buildings with at least a Green Mark Gold^{Plus} rating when their current lease expires.

d) Events and Functions:

Events and functions organised by public sector agencies are to be held in venues with at least a Green Mark Certified rating from 1 Jan 2015 onwards.

iii. Energy Efficiency

a) Indoor Air Temperature:

Public sector agencies must ensure that the indoor temperature of their air-conditioned premises is maintained at 24°C or higher.

b) Metering:

Data centres with more than 1,000 m^2 GFA are to install separate meters, and monitor and report their energy use.

iv. Water Efficiency

a) Water Efficient Building (WEB):

All new and existing public sector premises are to achieve water efficient flowrates / flush volume and attain Water Efficient Building (WEB) (Basic) certification respectively.

b) Water Metering:

Since June 2015, all new public sector premises which consume more than or equal to 36,000 m^3/year of water are to install private water meters at key water usage areas.

v. Waste Management

a) Recycling:

Public sector agencies are to implement recycling programmes which include initiatives to recycle paper, plastics, aluminium and toner cartridges.

b) Waste Reporting:

Owners of large public sector buildings with a gross floor area greater than 10,000 m^2 are to monitor and submit the weight / volume of waste disposed of and the weight of recyclables collected annually.

vi. Green Procurement

Public sector agencies are to procure the most cost-effective appliances, taking into account life cycle costs. New office information and communication technology equipment procured must meet the latest Energy Star standards.

Guaranteed Energy Savings Performance (GESP) Contracts

a) Improving energy efficiency is a key thrust under the PSTLES initiative. To ensure that the expected energy savings are realised, public sector agencies are encouraged to adopt the Guaranteed Energy Savings Performance (GESP) contracting model when undertaking building retrofit projects. As of December 2015, 23[7] large building owners have called GESP contracts for their building retrofit works. On average, these GESP contracts help building owners save 15% of their total electricity use, enabling public sector to save a total of $7 million per year. More details on guaranteed energy savings performance can be found in section 13.1.

9.2. Green Building Movement

In 2005, the Singapore Government embarked on the green building movement by launching the BCA Green Mark scheme. This is a green building rating system designed specifically for the tropics and sub-tropics. It serves as a benchmark for evaluating environmental sustainability in buildings.

The Green Mark criteria (for New Non-Residential Buildings) has recently been streamlined and enhanced to address sustainability in a more balanced and holistic manner. It looks into these five broad aspects:

i. Climate Responsiveness

   Focusing on effective leadership and collaborative teamwork to drive the overall environmental credentials of projects, consideration of the building's human centricity and whether it is in sync with its surrounding context/ locale, as well as the building passive design to enhance effective thermal comfort for its occupant.

ii. Building Energy Performance

   Focusing on optimising the efficiency of high consumption mechanical and electrical systems, holistic consideration of the effectiveness of energy systems' performance usage and consumption, as well as generation and utilisation of renewable energy;

iii. Resource Stewardship

[7] Source : National Environment Agency ; see http://www.e2singapore.gov.sg/

Encouraging responsible use of water in buildings through water efficient, monitoring and potable water replacement strategies, reducing the carbon footprint emerging from construction activities by promoting sustainable material and practices via a life cycle approach, as well as responsible management of the building construction and operational waste;

iv. Smart and Healthy Buildings

Ensuring good indoor air quality and spaces that are acoustically and visually comfortable, inclusive, and connect occupants to the natural environment, as well as smart building operation through optimising equipment and related processes for energy reduction and comfort requirements using automation, data and behavioural science;

v. Advanced Green Efforts

Recognising projects that demonstrate high levels of environmental performance without an increased capital expenditure, use of complementary certifications/ rating tools, as well as demonstration of the project's contribution to social sustainability.

The movement was spearheaded by the Building and Construction Authority (BCA). The focus under the first Green Building Masterplan was to encourage the adoption of new green buildings. In 2009, the focus shifted to greening the large existing building stock under the second Green Building Masterplan in order to achieve the key target of having "at least 80% of the buildings in Singapore to be green by 2030".

The number of green buildings in Singapore has grown exponentially. There were only 17 buildings in 2005, and this number grew to more than 2,800 as of September 2016. In terms of gross floor area (GFA), more than 84 million square meters of built-up space have been rated as 'green'.

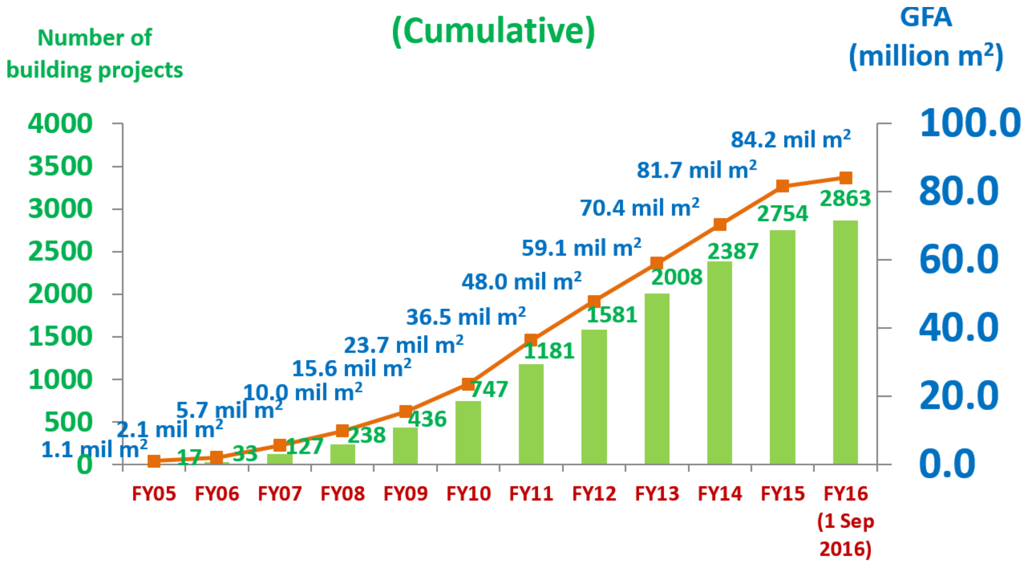


Figure 10: Number of Green Buildings[8] – as at September 2016

Since its launch in 2005, the BCA Green Mark Scheme has helped guide the design, construction and operation of buildings in increasing energy efficiency and enhancing environmental performance.

The scheme does not only apply to new and existing buildings, but also promotes environmental sustainability beyond buildings. This includes parks, supporting infrastructures, districts, rapid transit systems, and even occupant-centric spaces within buildings such as supermarkets and restaurants.

New Buildings
• BCA Green Mark for New Non-Residential Buildings • BCA Green Mark for New Residential Buildings • BCA Green Mark for Landed Houses • BCA Green Mark for Healthcare Facilities • BCA Green Mark for New Data Centres
Existing Buildings
• BCA Green Mark for Existing Non-Residential Buildings • BCA Green Mark for Existing Residential Buildings • BCA Green Mark for Existing Schools

[8] Source : BCA's 3rd Green Building Masterplan

- BCA Green Mark for Existing Data Centres

Beyond Buildings

- BCA Green Mark for Existing Parks
- BCA Green Mark for New Parks
- BCA Green Mark for Infrastructure
- BCA-LTA Green Mark for Rapid Transit System (RTS)
- BCA Green Mark for Districts

Within Buildings

- BCA Green Mark for Office Interior
- BCA Green Mark for Restaurants
- BCA Green Mark for Supermarkets
- BCA Green Mark for Retail

Figure 11: List of BCA Green Mark Schemes[9]

Since launching the Green Mark scheme in 2005, the BCA has trained and certified a pool of specialists who have the professional knowledge and ability to give advice on the design and operation of environmentally-friendly buildings. The target is to train 20,000 green specialists by 2020. As of September 2016, more than 15,000 have been trained, including Green Mark Managers (GMM), Green Mark Professionals (GMP), Green Mark Facilities Managers (GMFM) and Green Mark Facilities Professionals (GMFP).

The certified GMM is a competent professional or technical individual who possesses the knowledge and skills to participate in the design process, encourage an integrated design and facilitate the Green Mark Certification. The training of the GMP is aimed at developing competency to be able to carry out detailed design and enhancement of building performance for Green Mark Certification and implementation. To earn the certification as a GMP, the professional attends 22½ days of training exposing him to design challenges covering the following disciplines:

- Efficient Central Air-Conditioning Design, Operation and Maintenance
- Energy Efficiency Through Management & Audit
- Building Energy Modelling & Thermal Simulation

[9] For more details, please refer to https://www.bca.gov.sg/GreenMark/green_mark_criteria.html

- Solar Modelling
- Efficient Building Envelope Design, Envelope Thermal Transfer Value (ETTV) & Residential Envelope Transmittance Value (RETV)
- Indoor Air Quality (IAQ) Management for Buildings
- Building Automation Concepts, Technologies and Practices for Green Buildings
- Green Architecture & Integrated Design Process
- Energy Efficiency for Electrical Systems
- Sustainable Lighting Design and Technology
- Design & Simulation for Natural Ventilation
- Sustainable Hot Water & Heat Recovery Systems

For existing buildings, a certified GMFM is trained to operate the buildings in a sustainable way and to undertake sustainable improvement measures to reduce the building's environmental impact over its functional life cycle. At an advanced level, the certified GMFP is able to carry out detailed evaluation of energy efficiency retrofit and optimisation works on existing buildings and to manage and enhance the building performance to reduce the building's environmental impact over its life cycle.

In 2014, the third Green Building Masterplan was developed to engage building tenants and occupants more actively to drive energy consumption behavioural change and to address the well-being of the people. BCA's aspiration is for Singapore to become "A global leader in green buildings with special expertise in the tropics and sub-tropics, enabling sustainable development and quality living".

Results from the inaugural BCA Building Energy Benchmarking Report (released in September 2014) show that electricity usage by building owners and tenants account for 50% of the electricity consumption in commercial buildings. This placed a limit on how far efforts to drive sustainability can go unless there is a change in the building users' behaviour and consumption patterns. To do this, BCA forged wider collaborations and partnerships with key stakeholders including industry players, school community, building owners, tenants and the general public. BCA's key initiatives include the following[10]:

[10] Source : BCA's 3rd Green Building Masterplan

i. $50 million Green Mark Incentive Scheme for existing buildings and premises (GMIS-EBP)[11]

   a) Incentivises existing small and medium enterprise (SME) tenants and building owners, or building owners with at least 10% of its tenants who are SMEs to adopt energy efficiency

   b) Co-funds up to 50% of the retrofitting cost for energy improvement works or up to S$3 million for building owners and up to S$20,000 for tenants

ii. Building Retrofit Energy Efficiency Financing (BREEF) Scheme[12]

   a) To aid building owners in overcoming upfront costs of energy efficiency retrofits and in adopting Green Mark standards for existing buildings

   b) Increased risk share of 60% for any loan default with participating financial institutions

iii. Green Mark Gross Floor Area (GM GFA) Incentive Scheme[13]

   a) Encourages private sector to work towards achieving higher-tier Green Mark ratings

   b) Applicable to all new and existing private developments that undergo substantial energy efficiency enhancements

iv. SGBC-BCA Zero Capital Partnership Scheme[14]

   a) To provide a one-stop solution to existing building owners in carrying out retrofit works in their buildings with zero capital outlay.

   b) Energy Performance Contracting (EPC) firms which are accredited under the SGBC Singapore Green Building Services Labelling Scheme (SGBS) can finance and assist in the application of relevant grants or incentive schemes to fund the retrofit works, as well as facilitate the Green Mark certification of the buildings.

[11] For more details, please refer to https://www.bca.gov.sg/greenmark/gmisebp.html
[12] For more details, please refer to https://www.bca.gov.sg/GreenMark/breef.html
[13] For more details, please refer to https://www.bca.gov.sg/GreenMark/gmgfa.html
[14] For more details, please refer to http://www.sgbc.sg/wf-menu-install/zero-capital-partnership/zero-capital-partnership

v. Reaching out to building owners/tenants

a) Green Mark Portfolio Programme to certify similar spaces across a portfolio of projects
b) Green Lease Toolkit to provide good practice guidelines and to set sustainability targets between building owners and tenants
c) Improve sustainability standards in tenants' fit out and daily operations through Green Partnership Initiative Programme
d) Building capability and elevating industry's professionalism through professional accreditation
e) Green Mark Pearl Award to recognise developers and building owners who demonstrate thought leadership and efforts in engaging their tenants

vi. Greening schools and community for greater awareness

a) Green Schools Roadmap to facilitate greening of schools
b) Assists schools to conduct energy audits through Greenovate Challenge and Back to School programme
c) Achieve net zero energy in schools through installation of photovoltaic panels

Furthermore, BCA is addressing the information barriers and closing the energy loop through monitoring, sharing of information, and demonstrating building energy performance, taking the whole life cycle of buildings into consideration. By doing so, it also serves as a platform to improve the quality of the built environment and occupant well-being. BCA has initiated the following:

i. Annual mandatory submission of building information and energy consumption data[15]:

a) Developed the BCA Building Energy Benchmarking Report (BCA BEBR) since 2014 to share on the national building benchmarks
b) Monitors buildings' energy consumption to encourage pro-activeness in energy efficiency improvements and sustainable energy consumption behaviour of building occupants and users

[15] For more details, please refer to https://www.bca.gov.sg/BESS/Default.aspx/

ii. Mandatory minimum environmental sustainability standard for existing buildings[16]:

a) Meet minimum environmental sustainability standard upon installation and replacement of building cooling system

b) Applicable to all buildings with centralised cooling systems and Gross Floor Area of >5,000m^2.

iii. Mandatory periodic energy audit of the efficiency of building cooling systems and compliance with minimum standards:

a) Carry out energy audit on building cooling system to ensure systems operate efficiently throughout its life cycle

b) Applicable to new buildings that obtain their Planning Permission after Dec 2010 and existing buildings which have undergone major energy-use change on and after January 2, 2014

iv. Enhanced Indoor Environment Quality (IEQ) and post occupancy evaluation:

a) Review various building codes to achieve good indoor environmental quality

b) Ensure Green Mark certified facilities conduct regular indoor air quality audits

[16] For more details, please refer to https://www.bca.gov.sg/EnvSusLegislation/Existing_Building_Legislation.html (info extracted on 24 Oct 2016)

9.3. The Sustainable Singapore Blueprint 2015

Singapore's journey towards sustainability began in the 1960s. Back then, Singapore was a young nation facing high unemployment, urban slums, poor infrastructure, lack of sanitation and an unskilled labour force. The leaders in Singapore then had a long term vision for Singapore to be a sustainable garden city, and made decisions to green the country. Hence, the Sustainable Singapore Blueprint was developed.

Singapore published its first edition of the Sustainable Singapore Blueprint in 2009, and updated it in 2015. The key visions of the Sustainable Singapore Blueprint 2015[17] are:

i. A Liveable and Endearing Home

a) "Eco-Smart" Endearing Towns. As smart technology and eco-friendly features are embedded into the towns and homes, Singaporeans will enjoy greater convenience and a better quality of life. Enjoying time with family and friends will be easier with parks, ABC Waters projects, sports facilities, and other community amenities nearby. A green lifestyle will be second nature for many, with more ways for people to save energy and water at home. A second chute in some high rise residential buildings will enable residents to segregate their recyclables easily while keeping our environment clean.

b) A "Car-Lite" Singapore. With a denser rail network and extensive bus services, the population will be able to travel seamlessly and efficiently around the city. Cycling and walking will become popular forms of getting around in the neighbourhoods and regions. Electric car-sharing and driverless car trials will be conducted in parts of Singapore. A target was set to achieve a peak hour mode share of 75% for public transport by 2030, up from 64% in 2013. With a "car-lite" Singapore, the carbon footprint can be reduced, as well as bringing other benefits such as fresher air, a cleaner environment and a healthier lifestyle.

[17] Source: National Environment Agency (NEA); see http://www.mewr.gov.sg/ssb/files/ssb2015.pdf

ii. A Vibrant and Sustainable City

a) Towards a Zero Waste Nation. A goal is set towards becoming a Zero Waste Nation by reducing consumption of, as well as reusing and recycling all materials to give them a second lease of life. The Government, the community and businesses will come together to put in place infrastructure and programmes that make this a way of life. This is done by keeping Singapore clean and healthy, conserving precious resources, and freeing up land that would otherwise have been used for landfills, for future generations to enjoy.

b) A Leading Green Economy. Businesses will adopt greener practices, making the city a hub for the cutting-edge business of sustainable development. Singaporeans can enjoy jobs in this exciting and meaningful sector. Living Labs will be created to test-bed ideas that improve lives and that are good for the environment. This may be done by raising solar penetration rates and having 80% of our buildings achieve the BCA Green Mark standard by 2030, up from 25% today. Businesses in Singapore will be internationally recognised for doing well by doing good.

iii. An Active and Gracious Community

a) Singaporeans are at the heart of this Blueprint. The people, young and old, are the beneficiaries of its desired outcomes. At the same time, the people's collective efforts and commitment today are needed to realise the outcomes in this Blueprint. Singaporeans must become exemplary stewards of our environment. This might be done by participating in shaping the neighbourhoods and building a more gracious society together. It should be second nature for people, businesses and the Government to come together to care for the common spaces and the environment, taking a long-term perspective in conserving precious resources, and championing a sustainable way of life.

The energy management team can play an active role in helping the country realise these objectives. In the section on "A Vibrant and Sustainable City", some targets are set to make Singapore a leading Green Economy. The initiatives under this section are:

i. Introduce new innovation districts such as the integration of CleanTech Park, Nanyang Technological University, future industrial estates like Bulim and Jalan Bahar, and Tengah, as a living laboratory that fosters creativity and innovation
ii. Plan to raise the adoption of solar power in our energy system to 350 MWp by 2020. To this end, create lead demand for solar deployment through the SolarNova programme
iii. Test more green innovations, including a Renewable Energy Integration Demonstrator – Singapore test-bed on Semakau Landfill
iv. Develop a $52 million Green Buildings Innovation Cluster to grow our capability in developing green buildings
v. Create more green, quality jobs, from an estimated 60,000 in 2011
vi. Launch initiatives to encourage Singapore based companies to adopt best-in-class sustainability practices

The resource sustainability targets[18] under this section are:

i. 80% of buildings to achieve BCA Green Mark Certified rating
ii. 35% energy intensity improvement (from 2005 levels)
iii. 140 L of domestic water consumption per capita per day
iv. 70% national recycling rate
v. 30% domestic recycling rate
vi. 81% non-domestic recycling rate

[18] Source : Sustainable Singapore Blueprint 2015

9.4. Legislation and Incentives

Besides playing an active role in promoting energy efficiency and sustainability, the Singapore government employs several measures to encourage facility owners to embark on energy efficiency projects. Below are several public policies using legislative powers and incentives to achieve energy efficiency.

9.4.1. Energy Conservation Act

Energy efficiency related legislation across various sectors are consolidated in an Energy Conservation Act. The Act includes mandatory energy management requirements for energy intensive companies in the industrial sector. With effect from 22 April 2013, such companies are required to register with NEA within 6 months of qualifying as a registrable corporation.

A corporation is a registrable corporation if it meets the following qualifications:

- It has operational control over a business activity which has attained the energy use threshold (54TJ or more of energy used per calendar year) in at least 2 out of the 3 preceding calendar years; and
- The business activity is carried out at a single site and is attributable to one of the following sectors:
  - i. manufacturing and manufacturing-related services;
  - ii. supply of electricity, gas, steam, compressed air and chilled water for air-conditioning; and
  - iii. water supply and sewage and waste management

Once registered, corporations will be required to implement the following energy management practices:

i. appoint an energy manager;
ii. monitor and report their energy use and greenhouse gas emissions annually; and
iii. submit energy efficiency improvement plans annually.

By improving their energy performance, companies can become more competitive in the global economy. The Act also seeks to complement on-going schemes and capability building programmes which provide support for companies investing in energy efficiency.

9.4.2. Energy Efficiency Improvement Assistance Scheme (EASe)[19]

The foundation of a good energy management strategy is an energy audit of an existing building or facility with the objective of improving its energy efficiency. It is an investigation involving a detailed analysis of energy flows into and out of a facility. The aim is to identify and quantify areas where energy savings can be made and estimate the amount of savings achievable. These may include improvements to facility design, operation and management.

Companies are encouraged to engage the services of an accredited Energy Services Company (ESCO) who are specialists in conducting energy audits. The government through this EASe scheme co-funds up to 50% of qualifying costs of engaging an ESCO; capped at $200K for any single facility or building.

9.4.3. Grant for Energy Efficient Technologies (GREET)[20]

The Grant for Energy Efficient Technologies (GREET) aims to encourage owners and operators of new and existing industrial facilities to invest in *energy efficient equipment or technologies.* The scheme is co-administered by the National Environment Agency and the Singapore Economic Development Board.

GREET co-funds as much as 20% of investment cost of energy efficient equipment or technologies. Qualifying costs include manpower, equipment and materials, and professional services. Capped at $4 million per project, GREET encourages the installation of energy efficient technologies or equipment.

9.4.4. Design for Efficiency Scheme (DfE)[21]

Experience has shown that retrofitting existing facilities is generally more expensive than introducing energy efficiency measures at the design stage. So

[19] Source : National Environment Agency (NEA) ; see http://www.nea.gov.sg/energy-waste/energy-efficiency
[20] Source : National Environment Agency (NEA) ; see http://www.nea.gov.sg/energy-waste/energy-efficiency
[21] Source : National Environment Agency (NEA); see http://www.nea.gov.sg/energy-waste/energy-efficiency

the opportunity to incorporate energy efficiency at the design stage should be seized. This is the most cost effective approach to improving energy performance of the facility. Many system design synergies are only available early in the design process before system choices are locked in. We find in many facilities that on-site utilities and supply utilities tend to be oversized at the expense of energy efficiency. If the principles of right sizing are applied, the facilities can be energy and resource efficient. This can reduce the capital cost of the systems (due to reduced capacity needs in upstream utility systems) and achieve dramatic savings in resource use. Therefore energy and resource efficiency can lead to lower capital cost, lower operating cost and lower maintenance costs.

Investors are encouraged to integrate energy and resource efficiency improvements into manufacturing development plans early in the design stage. In addition to the early engagement of all stakeholders including consultants and contractors, a visiting team of technical experts can facilitate the design process with an eventual goal of attaining energy efficiency. To encourage this, the design for efficiency scheme co-funds 80% of the cost of design workshops or $600,000 whichever is lower.

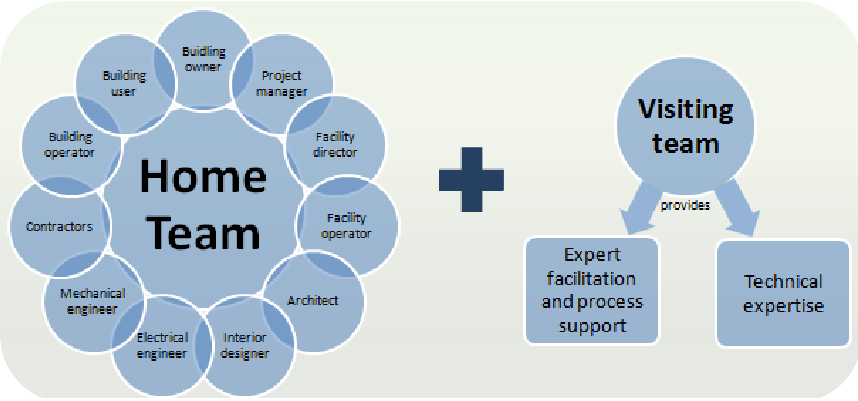


Figure 12: Engaging a visiting team of technical experts

(Source : http://www.e2singapore.gov.sg/Incentives/Design_for_Efficiency_Scheme.aspx)

9.4.5. One-Year Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology[22]

[22] Source : National Environment Agency (NEA) ; see http://www.nea.gov.sg/energy-waste/energy-efficiency

This tax incentive scheme encourages companies to replace old, energy-consuming equipment with more energy efficient ones and to invest in energy-saving equipment. Inefficient equipment not only incur high operating costs as they consume more energy but also have a negative impact on the environment as a result of higher emission of pollutants to the environment.

The Income Tax Act allows companies to write off the capital expenditure on the qualifying energy efficient or energy saving equipment in one year instead of three years. So, while the companies enjoy the benefit of accelerated depreciation of the capital expenditure, they are also contributing to a better environment.

9.4.6. Investment Allowance (IA)

This is another scheme to encourage industry to invest in capital equipment that allows them to be more energy-efficient in their operations.
Depending on the extent of improvement in energy efficiency, companies may be given an allowance of 30% of approved fixed capital expenditure on top of the normal 100% capital allowance. This may apply at the facility level, equipment or system level.

9.4.7. Innovation for Environmental Sustainability Fund (IES)

The IES fund aims to encourage and assist Singapore-registered companies to undertake environmental protection and public health related projects that would contribute to the long-term environmental sustainability of Singapore. The IES fund is targeted at projects at the applied research and test-bedding/demonstration stages of technology developments.

The proposed IES projects shall target to achieve at least one of the following objectives:

i. Initiatives that speed up environmentally sustainable applications;
ii. Innovative proposals that have the potential to create new value and capabilities for NEA; and
iii. Projects that offer long-term solutions to specific environmental problems faced by Singapore.

9.4.8. Energy Efficiency National Partnership (EENP) Programme

In 2010, the NEA launched an industry-focused Energy Efficiency National Partnership (EENP) programme. This is a voluntary partnership programme for companies that wish to be more energy efficient, thereby enhancing their long-term business competitiveness and reducing their carbon footprint. The EENP aims to support companies in their energy efficiency efforts through learning network activities, provision of energy efficiency-related resources, incentives and recognition. EENP Partners will work towards adopting in-house energy management systems which involve appointing energy managers, developing energy policies, establishing energy targets and implementing energy efficiency improvement plans.

The EENP is targeted at:

i. Companies that are interested in improving their energy efficiency and implementing energy management practices.
ii. Companies that are large energy consumers especially those that consume 54TJ of energy or more per year.

The companies in the second group include those required by the Energy Conservation Act to appoint an energy manager, monitor and report energy use and greenhouse gas emissions, and submit energy efficiency improvement plans. As at April 2016, there were some 230[23] companies that have joined this EENP programme.

The programme comprises three components.

i. Energy Management System

Partners will be encouraged to adopt an Energy Management System at the organisational level so that the measurement and

[23] Source : National Environment Agency; see http://www.e2singapore.gov.sg/Programmes/Energy_Efficiency_National_Partnership.aspx

management of energy consumption, as well as the identification of energy efficiency improvements, can be undertaken systematically.

ii. EENP Learning Network

The Learning Network aims to provide opportunities for the industry to learn about energy efficiency ideas, technologies, practices, standards and case studies.

This includes platforms such as high level fora that are targeted at top management, conferences and technical workshops targeted at senior and middle management teams and technical staff, and learning journeys. Energy efficiency technical workshops on industrial systems will also be organised to provide intensive training to engineers and practitioners in energy efficiency so as to develop their capabilities. The EENP Learning Network will be augmented by energy efficiency benchmarking studies that would be conducted in collaboration with industry, to help companies to determine their energy efficiency improvement potential and identify cost-effective measures that they can implement to improve energy productivity.

iii. EENP National Recognition Scheme

The EENP National Recognition Scheme (known as EENP Awards) recognises the efforts and achievements of corporations and corporate teams in excellent energy management practices and in improving energy efficiency.

9.4.9. Training in Energy Management

The Singapore Certified Energy Manager (SCEM) Training Grant is a co-funding scheme administered by e2i[24] to develop local expertise and capability in professional energy management. Candidates who have completed the training at Associate Level or Professional Level and meet the necessary criteria can apply for ASCEM and SCEM certifications respectively.

[24] e2i is the Employment and Employability Institute

The SCEM programme is designed for engineering professionals who intend to build their career as energy managers. It gives a thorough understanding of the key energy issues. The programme will help the participants to develop the technical skills and competencies needed to manage and track energy usage within the organisations they serve.

A SCEM is envisioned as a competent energy professional equipped and qualified to perform technical and managerial functions in the areas of

i. Energy audits, management and measurements;
ii. Energy retrofitting services;
iii. Financial advisor for energy efficiency measures and contracting;
iv. Consultation and Procurement services;
v. Facility and energy management; and
vi. Energy engineering works.

There are three training levels for SCEM, namely Associate Level, Professional Level and Executive Level, catering to applicants with different educational and training backgrounds.

i. Associate Level

   Associate level SCEM training focuses on skill training and practical development in energy auditing works, installations, measurements and instrumentations.

ii. Professional Level

   Professional level SCEM training focuses on the theory and practice of energy management, energy efficiency and analysis, procurement, finance and economics. The training aims to develop competency in energy audit works, energy performance contracting and project management, energy efficiency analysis, energy economics and financial assessment. Participants will eventually identify saving potentials and make sound recommendations and proposals.

iii. Executive Level

Executive level SCEM courses are short courses meant to give participants who are executives and senior management awareness of energy efficiency related topics thus allowing them to promote energy efficiency in their organisations. These courses are non-certifiable.

9.4.10. Efforts by BCA and Singapore Green Building Council (SGBC) in encouraging EE retrofits

In Singapore, the Singapore Green Building Council (SGBC) accredits a group of Energy Performance Contracting firms (EPC)[25], which have track record of delivering retrofit projects under an EPC arrangement. Both guaranteed and shared savings models are commonly offered by these firms, with some firms making slight variations to the EPC model to suit their business needs.

Both models require either the EPC firm or the building owner to source for financing for the project, either through internal funds or through loans. Commercial loans for such projects are usually small in quantum or of short tenure. This is not adequate due to the nature of the energy efficiency retrofit projects, which typically costs around S$1 to 2 million, with average payback period of 4 to 6 years.

For most building owners, energy efficiency retrofit projects are usually classified as maintenance works and they usually have a low priority on the agenda of top management. Most EE projects are not implemented due to budget limitations and concerns on financing of upfront costs. For buildings owned by a Management Corporation Strata Title (MCST), the sinking fund is usually intentionally kept thin, just enough to cover day to day operations or maintenance costs. High investment items such as the air-conditioning system, lighting replacement may need additional contribution from the subsidiary proprietors. The proposal will not likely reach a binding decision if the equipment are still working, albeit inefficiently.

Financial institutions, on the other hand, are not attracted to EE projects as they are not familiar with EE technologies and find it hard to appraise such projects as the energy savings are projected based on engineering calculations. It is

[25] Singapore Green Building Council, List of Certified Energy Performance Contracting Firms.

also difficult for borrowers such as the EPC firms and MCSTs to pass the stringent credit evaluation. For the EPC firms, most which require financing are considered "young", local Small, Medium Enterprise (SME) companies with few years of track record and have a weak balance sheet. For the MCSTs, the thin balance sheet also makes credit evaluation difficult.

Recognising the market gap, the Building and Construction Authority (BCA) launched the pilot Building Retrofit Energy Efficiency Financing (BREEF) scheme[26] to provide credit facilities to commercial building owners, MCSTs, accredited EPC firms and Energy Services Companies (ESCOs) for EE retrofits under an EPC arrangement. The scheme provides financing for the purchase and installation of energy efficient equipment.

Under the scheme, BCA co-shares 60% of default risks with the Participating Financial Institutions (PFI) to offer loans of up to S$5 million, with tenure of up to 8 years per project. This helps to address the perception that EE loans are riskier than other conventional loans. By sharing the risk, the PFI's financial risk is reduced and thereby motivates the PFI to increase its lending to EE projects. The partnership also helps to provide technical capacity building to the PFIs to increase their understanding on EE projects and in turn, encourage PFIs to finance such projects. To ensure that the building projects continue to sustain their performance, buildings financed by BREEF have to maintain their Green Mark certification throughout their loan tenure.

EPC firms, MCSTs, building owners and PFIs welcome BREEF as a necessary move to support the EE retrofit market. While government programs such as incentives can help to improve the business case of EE retrofits, this has to be complemented with financing schemes to help those that are not financially strong to cope with the upfront capital cost.

As of July 2015, the BREEF scheme has helped to finance 10 building retrofit projects, with total approved loan amount of more than S$16 million.

[26] Building and Construction Authority, Building Retrofit Energy Efficiency Financing scheme. (http://www.bca.gov.sg/GreenMark/breef.html)

Amongst the BREEF applications, there is a trend of ESCOs borrowing on behalf of the building owners. Building owners prefer to adopt an Energy Performance Contract (EPC) arrangement where EPC firms fund retrofits on their behalf and they will then repay the ESCOs through energy savings reaped over a period of time. This arrangement is favoured as it simplifies the decision making process by alleviating the technical and financial issues.

Besides financing, BCA also has incentives in place. The $100 million Green Mark Incentive Scheme for Existing Buildings (GMIS-EB)[27] was first launched in 2009 to encourage commercial building developers and/or commercial building owners to adopt energy efficient retrofitting design, technologies and practices in their existing buildings to achieve a significant improvement in the building energy efficiency. There are 2 parts to the scheme:-

(a) A cash incentive for upgrading and retrofitting that co-funds up to 50% (capped at $3 million) of the costs of supply and installation of energy efficient equipment and professional services to improve the energy efficiency of existing buildings.

(b) A 'health check', which is an energy audit to determine the efficiency of the air-conditioning plants. BCA will co-fund 50% of the cost for conducting this Health Check and the remaining 50% will have to be borne by the building owner.

The GMIS-EB scheme for cash was fully committed as at April 2014 while the ‘health check’ is still available. To further accelerate the “greening” of existing buildings and enabling tenants and occupants to play a bigger role in Singapore’s green building movement, a new $50 million Green Mark Incentive Scheme for Existing Buildings and Premises (GMIS-EBP)[28] was launched in October 2014. This is Government’s first targeted initiative in engaging the SME building owners and tenants, to embark on environmental sustainability and improving energy efficiency (EE) standards of their buildings and premises. For building owners’ application, they must be SMEs or have at least 30% of their

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[27] Building and Construction Authority, Green Mark Incentive Scheme for Existing Buildings. (http://www.bca.gov.sg/GreenMark/gmiseb.html)
[28] Building and Construction Authority, Green Mark Incentive Scheme for Existing Buildings and Premises. (http://www.bca.gov.sg/GreenMark/gmisebp.html)

tenants who are SME. For tenants' application, the applicant must be an SME. The scheme provides a cash incentive amounting to up to 50% of the qualifying costs incurred solely for the purposes of energy efficiency improvements in existing buildings and premises.

BREEF and the incentive schemes complement each other well, with the former helping building owners address upfront capital costs issues and the latter improving the investment payback of retrofits, encouraging building owners to strive for higher energy efficiency improvements. The schemes have helped to fund the installation of a number of energy efficient equipment, which include chilled water system replacement, heat pumps installation, and lighting replacement to energy efficient types.

Exercises (I)

Question 1.1
You have been appointed the energy manager of a manufacturing plant that employs some 300 people. You have been asked to brief the executive management on the energy management process. How might you describe this process in your presentation?

Question 1.2

You are an employee in a factory and this plant has a staff strength of 200 people. The various departments in the company are

Facility / Maintenance Department

Production Department

Finance Department

Sales and Marketing Department

Human Resource Department

You have been appointed the energy manager. Who should be represented in your energy management team? State their roles and responsibilities.

Question 1.3

Calculate the fixed energy consumption for a rolling mill consuming 300,000 kWh of electricity to produce 500 metric tons (MT) of products per month and having specific energy consumption of 500 kWh per metric ton (MT).

Question 1.4

Which of the following energy management activities will not help reduce greenhouse gases?

a) Reduce energy costs by reviewing tariff rates
b) Improve part load performance of chillers
c) Replace energy inefficient equipment
d) Turn off artificial lighting in the office during lunch time

Question 1.5

Assuming a hospital with a total of 5000 in-patient beds. The hospital uses both electrical energy and thermal energy to serve its activities in the building. The hospital collects energy consumption data (electricity and thermal separately) and the utilisation rate of in-patients beds on a monthly basis. Total floor area of the hospital is 50,000 m^2. Annual service hours is 8,760 hours. In this case what should be the most appropriate EEI for this hospital?

Question 1.6

What are your roles and responsibilities as the energy manager with regards to the Energy Conservation Act?

References

1. Building and Construction Authority (BCA), “3rd Green Building Masterplan”, 2015

2. Ministry of the Environment and Water Resources and Ministry of National Development, “Sustainable Singapore Blueprint 2015” , 2015

3. ASHRAE Handbook – Application 2013

4. SS ISO 50001:2011

5. ASEAN Energy Management Scheme (AEMAS)

Suggested Reading materials

6. Freeman, S. David. “Winning our Energy Independence.” 2007

7. Friedman, Thomas L. “Hot, Flat And Crowded – Why The World Needs A Green Revolution – And How We Can Renew Our Global Future”, 2008

8. Senge, Peter, et al. “The Necessary Revolution – How Individuals And Organisation Are Working Together To Create A Sustainable World”. 2008

Part II –

Overview of the Energy Market in Singapore

10. Energy Supply and Demand in Singapore

10.1 Introduction and Learning Outcomes

Introduction

The energy market is a dynamic one. Consumers in Singapore had always bought electricity from a government agency until 2008 when some large consumers became contestable. From a monopoly run by the government, the electricity and gas markets are now operated by private enterprises. The government now plays a regulatory role. As the market opens up further, more players and more products will enter the scene. Energy prices have been especially volatile in the past few years, oil prices fell from over US$100 a barrel to just US$30 a barrel within some months in 2015. The energy manager must therefore be keenly aware and alert to the changing scenarios.

Chapters 10 and 11 provide an overview of the energy market in Singapore. As new policies and regulations are being introduced by the government, it is recommended that readers check the website of several government agencies to keep abreast of new developments. The website most useful for the materials covered in Chapters 10 and 11 is "www.ema.gov.sg ", the official website of the Energy Market Authority.

Learning Outcomes

At the end of this second part, the reader should be able to:

1. understand Singapore's energy market tariff structure
2. evaluate supply contracts for reducing energy costs

10.2 National Electricity Market of Singapore (NEMS)

Singapore began restructuring its electricity market in the late 1990s and by January 2003, the National Electricity Market of Singapore (NEMS) commenced with the following objectives:

i. promote efficient supply of competitively priced electricity;
ii. open up the retail market eventually to full competition;
iii. allow certain government owned assets to be privatised; and
iv. encourage private investment in Singapore's power system infrastructure

Since 1995, government owned assets have been structured to facilitate commercialisation and subsequent privatisation. In 1998, the Singapore Electricity Pool came into operation. The NEMS represents a progression from the Pool to fully competitive wholesale and retail electricity markets.

By 2008, three large generation companies were divested. Tuas Power was sold to Huaneng Group; Senoko Power was sold to Lion Power Holdings, and PowerSeraya was sold to YTL Power International Berhard.

The retail electricity market has been progressively liberalised to allow more consumers to choose their electricity retailer. The larger companies and consumers were made contestable first, through to the small households last. In the interests of fairness, the rules for contestability have been determined and enacted in the Electricity Act.

Since July 2001, consumers with a maximum power requirement of 2 MW and above were given the option to choose whom they wished to buy electricity from. In June 2003, consumers with an average monthly consumption of 20,000 kWh and above could become contestable. Currently, a commercial or industrial consumer with an average monthly electricity consumption of at least 2,000 kWh (the monthly electricity bill is about $450) is eligible to become contestable. In total, about 89,500 accounts (or 33,000 consumers) are eligible to be contestable.

There are 1.3 million small consumers which are mainly households who are still not contestable. The Energy Market Authority (EMA) is working towards *Full Retail Contestability* where the small consumers will have the option to choose whether they want to remain on the regulated tariff or switch to buy electricity from retailers at market prices.

In 2014, Singapore consumed 46,400 GWh of electricity with a peak demand of around 7,000 MW. The industrial sector consumed 42.6%[29] of the electricity generated, the commercial and service sectors 36.5%, household 14.9% and transport 5.3%. This demand is projected to grow between 2% to 4% per annum based on Gross Domestic Product (GDP) and population growth forecast.

[29] Source : Singapore Energy Statistics 2015

10.3 Gas Demand and Supply

Currently there are two separate networks for gas supply – town gas and natural gas. City Gas Pte Ltd is the retailer of town gas or manufactured gas as it is sometimes called. About 50% of the households in Singapore get town gas piped into their homes, providing energy for cooking and heating water.

For years, Singapore's demand for natural gas was predominantly met by pipeline supplies from neighbouring countries. By 2015, about 95% of all electricity generated in Singapore was generated from natural gas. To diversify and secure its energy sources, Singapore developed a Liquefied Natural Gas (LNG) terminal in 2013 to procure natural gas from markets further afield,

LNG is a natural gas transported in the liquid state. By a refrigeration process, the gas is liquefied to -160°C at atmospheric pressure. The main exporters are Qatar, Malaysia and Australia.

The Energy Market Authority (EMA) has appointed a LNG aggregator, BG Singapore Gas Marketing Pte Ltd. This company has to aggregate the demand for LNG from all end-users and procure the required amount of LNG. It has the exclusive rights to import LNG and sell regasified LNG in Singapore for up to three (3) million tons per year or until 2023.

The EMA has also licensed companies involved in the transport, import, shipping and retail of gas, as well as operators of the Liquefied Natural Gas terminal and onshore receiving facilities for piped natural gas.

The gas transporter owns and manages the gas pipeline network for conveying natural gas and town gas in Singapore. It is also responsible to provide open and non-discriminatory access to the gas pipeline network. To ensure high quality of service delivery by the gas transporter, EMA has set performance standards which include the following service dimensions,

i. availability of supply,
ii. reliability of supply,
iii. gas emergencies,
iv. providing supply, metering services; and
v. customer contact.

PowerGas Ltd is licensed by EMA as the Gas Transporter.

Gas shippers enter into a contract with the gas transporter to convey gas through the gas pipeline network. These entities must have a valid Gas Shipper Licence issued by EMA. Listed below are companies engaging in gas shipping activities.

i. City Gas Pte Ltd
ii. Gas Supply Pte Ltd
iii. Keppel Gas Pte Ltd
iv. YTL PowerSeraya Pte Ltd
v. Senoko Gas Supply Pte Ltd
vi. SembCorp Gas Pte Ltd
vii. PacificLight Power Pte Ltd
viii. Tuas Power Generation Pte Ltd
ix. Tuaspring Pte Ltd
x. Pavilion Gas Pte Ltd
xi. BG Singapore Gas Marketing Pte Ltd

11. National Electricity Market of Singapore (NEMS)

11.1. Main Players and Their Roles and Responsibilities

The key parties involved in the NEMS are:

a) *The Regulator* – the EMA has the task of regulating the electricity sector and has the ultimate responsibility for ensuring that the NEMS meets the needs of Singapore.

b) *The Market Operator* – the Energy Market Company (EMC) is the company that will operate and administer the wholesale markets. It is owned by the EMA and M-co International, with majority ownership resting with the EMA.

c) *The Power System Operator (PSO)* – the PSO is a division of the EMA responsible for ensuring the reliable supply of electricity to consumers and the secure operation of the power system. The PSO controls the dispatch of electricity in the wholesale market, coordinates outage and emergency planning and directs the operation of the Singapore high-voltage transmission system under the terms of an "operating agreement" with SP PowerAssets Ltd, the transmission licensee.

d) *The Transmission Licensee* – SP PowerAssets Ltd owns and is responsible for the operation and maintenance of the transmission system. SP PowerAssets Ltd has engaged SP PowerGrid Ltd as the authorised managing agent to carry out the management and operation of all aspects of the regulated transmission and distribution business, for and on behalf of SP PowerAssets Ltd.
SP PowerAssets Ltd recovers its costs of providing transmission services via grid charges. In general the grid charge structure is made up of the contracted capacity charge (fixed component) and the usage charge (variable component), which is further sub-divided into the peak charge and the non-peak charge.

The various classes of customers served by SP PowerAssets Ltd are:

i. Ultra High Tension – for consumers taking ultra-high tension supplies (230kV and above)
ii. Extra High Tension – for customers taking extra-high tension supplies (66kV)

iii. High Tension – Large – for consumers taking high tension supplies (22kV and 6.6 kV) with a contracted capacity of at least 1700 kW
iv. High Tension – Small – for consumers taking high tension supplies (22kV and 6.6 kV) with a contracted capacity of less than 1700 kW
v. Low Tension - Large – for large industrial and commercial consumers taking low tension supplies (400V/230V). These are contestable consumers with time-of-day metering
vi. Low Tension - Small – for all non-contestable consumers taking low tension supplies

e) *Generation Licensees* – all generators with facilities with capacity of 10 MW or more must be licensed by the EMA. All generators with capacity of 1 MW or more but less than 10 MW are required to register with the EMC as market participants either for dispatch or for settlements only. All facilities with capacity of 10 MW or above must be registered for dispatch. Mandatory participation ensures that all generators of any significant size are subject to the Rules[30].
Singapore has seen rapid growth in its electricity generation volume and capacity, as well as in its peak demand, in line with Singapore's high rate of economic growth. Peak demand has been growing at 5.6% per annum compounded and total electricity generation volume grew at an average compounded rate of 5.9% per annum between 1995 and 2004, increasing by a total of 67% in nine years.

Any company that wishes to generate electricity in Singapore must apply to the EMA for a generation licence, specifying the capacity of each planned generation facility. If an existing generator intends to expand their generation facilities over what is allowed by their licence, the company is required to apply for a modification of the licence to that effect. Similarly, cross-ownership restrictions require that EMA approval be sought in the event that a generation company intends to acquire a stake in any other Singapore generator licensee. However, there currently is no restriction on a single entity having both generation and retailing businesses. For example, Senoko Energy Supply (a retailer) is a wholly-owned subsidiary of Senoko Power (a generator).

[30] Singapore Electricity Market Rules, (https://www.emcsg.com/marketrules)

A key aim of the Singapore Government in deregulating the Singapore electricity market is to continue encouraging the addition of new generation capacity, but at the same time eroding the market power of incumbent Generators. For this reason, all 7 licensed generation companies have a specified licensed generation capacity. The licensed capacity includes current capacity in commercial operation and capacity yet to be commissioned. Not all of this capacity is currently committed to be built.

To curb the exercise of market power by the larger incumbent generators, they are required to enter into vesting contracts. The quantity of hedges allocated to each generator under the vesting contracts will reduce as new generation plants are built and the market power of the larger incumbent generators diminishes. Vesting contracts will continue as long as the EMA considers that market power persists and it is expected to be at least 10-12 years before market power is substantially diluted. More details on vesting contracts can be found in section 11.8

f) *Market Support Services Licensees* – MSSLs provide market support services such as

i. Reading electricity meters and managing the data relating to meter reading;
ii. Facilitating access to the wholesale electricity market for contestable consumers and retail electricity licensees;
iii. Facilitating the transfer of contestable consumers between retailers; and
iv. Supply electricity to non-contestable consumers.

Since the start of the NEMS, SP Services Ltd (formerly known as Power Supply Ltd), is the sole MSSL. As a monopoly supplier, SP Power charges regulated fees (approved by EMA) to its customers for market support services provided. The MSSL has a specific role in the settlement of vesting contracts. The MSSL is the counterparty to the generators for vesting contracts and will calculate and settle vesting contracts with consumers or their retailers.

g) *Retail Electricity Licensees* – all retailers must be licensed by the EMA. Retailers are permitted to sell electricity to contestable consumers. Market Participant Retailers (MPRs) are registered with the EMC as market participants in order to purchase electricity directly from the wholesale market. Non-Market Participant Retailers (NMPRs) are not registered with the EMC and purchase electricity directly through a MSSL. When a contestable consumer signs a contract with a retailer, it pays for energy at the price agreed in their contract. The retailer may also offer the consumer other services, including billing and collecting of transmission charges payable by the consumer. As more consumers become contestable, the role of the retailers is expected to increase significantly.

h) Retail companies have the option to choose whether to purchase electricity directly in the Wholesale Energy Market (WEM), as a Market Participant Retailer (MPR), or as a Non-Market Participant Retailer (NMPR) through the Market Support Services Licensee (MSSL). There is no consumer (demand-side) bidding for energy in the NEMS at this time. Load for each period is estimated by the EMC based on information provided by the PSO. Therefore entities that purchase their electricity in the WEM, including MPRs and the MSSL, must purchase it at the spot price, Uniform Singapore Energy Price (USEP).

A MPR has the right to:

i. retail electricity;
ii. trade in any wholesale electricity market operated by the EMC;
iii. import and export electricity, if permitted by its licence; and
iv. apply for any compensation as allowed for in the Rules.

A MPR is obliged to:

i. obtain a licence from the EMA;
ii. apply to the EMC for registration as a market participant;
iii. comply with the applicable sections of the Rules [31];
iv. enter into the following agreements:

[31] The Singapore Electricity Market Rules (Market Rules) govern wholesale operations of the NEMS; refer to https://www.emcsg.com/marketrules

a) A regulatory contract with the MSSL (for market support services)
b) A retailer agreement with SP PowerAssets Ltd (for collection of usage of Service (UoS) charges)
c) A regulatory contract with the PSO

v. inform its customers of any emergencies or security issues which may affect the sale of electricity to these customers;

vi. take such action as the PSO may require related to emergency preparedness and restoration of the power system;

vii. perform the duties under its license in a manner which is consistent with the Government of Singapore's obligations including the Government being a member of an international organisation or a party to an international agreement;

viii. monitor its activities with respect to compliance with its license and report any suspected non-compliance to the EMA;

ix. inform the EMA where an offence has been committed in respect of its activities or property; and

x. allow the EMA such access or control of its property as required to permit the EMA to meet its obligations under any special administration order.

A further difference between a MPR and a NMPR is that additional investment will be required for a MPR to ensure its systems and processes are of adequate specifications to participate in the wholesale market. While a NMPR will not have these costs, it will be charged a mark-up margin for the energy it purchases from the MSSL to cover the cost of procurement.
Additional differences between MPRs and NMPRs are as follows:

i. A Market Participant Retailer (MPR):
   a) Is directly responsible for technical compliance with the Rules;
   b) Must satisfy the EMC prudential requirements as part of registration; and
   c) Can settle its bilateral contracts through the EMC.

ii. A Non Market Participant Retailer (NMPR):

a) Satisfies technical and prudential requirements of the Rules through the MSSL; and

b) Settles bilateral contracts outside the EMC settlement system.

Table 2: Singapore National Electricity Market (NEM)

Singapore National Electricity Market (NEM)	
Key Players	**Roles & Responsibilities**
The Regulator	EMA is the Regulator of the electricity sector and is responsible of ensuring that the NEM meets the needs of Singapore
Market Operator	EMC operates and administers the wholesale market
Power System Operator	PSO is responsible for ensuring the reliable supply of electricity and secure operation of the power system
Transmission Licensee	SP Power Assets owns and is responsible for the operation and maintenance of the transmission system
Generation Licensees	All facilities of 10 MW or more must be licensed by EMA. Mandatory participation ensures all generators are subject to market rules Generators with facilities > 1MW but < 10MW register with EMC for dispatch or for settlements only
Market Support Services Licensees	MSSL provides market support services such as meter reading and meter data management Also facilitate access to the wholesale market for contestable consumers and retailers Responsible for supplying electricity to all non-contestable consumers
Retail Electricity Licenses	Retailers are permitted to sell electricity to contestable consumers
Consumers	Consumers are categorised into contestable and non-contestable depending on their annual electricity usage

i) *Consumers* – consumers are divided into contestable and non-contestable, depending on their annual electricity usage. Contestable consumers may purchase electricity from a retailer, a MSSL or directly from the wholesale market (provided in the latter case that they are licensed by the EMA to trade in the wholesale market and are registered with the EMC as market participants). Non-contestable consumers are required to purchase their electricity supply through a MSSL. More details on contestability can be found in section 11.2.

11.2 Contestable and Non-Contestable Consumers

One immediate impact of the NEMS is the shifting of risks from consumers to energy producers and suppliers. The electricity markets have transformed energy companies from regulated monopolies into market-driven suppliers of competitively priced energy and related services. Deregulation opened the industry to competition and increased demand for lower priced, innovative products. Energy companies today need to maximise profits while managing risks. They now need risk management skills, processes and technology that were unnecessary in the past.

The consumers are categorised into two groups – contestable and non-contestable consumers. The threshold for contestability has been progressively lowered over the years:-

i. in 2001, for those whose monthly consumption exceeded 20,000 kWh
ii. in 2003, for those whose monthly consumption exceeded 10,000 kWh
iii. in 2014, for those whose monthly consumption exceeded 4,000 kWh
iv. in 2015, for those whose monthly consumption exceeded 2,000 kWh

<u>Contestable Consumers</u>

Contestable consumers are large high tension and low tension users with consumption above 2,000 kWh per month. They include big users such as petrochemical companies, manufacturing companies and shopping malls, to smaller users such as coffee shops, kindergartens, and community establishments. By 2015, some 33,000 commercial and industrial (C&I) consumers participated in the contestable market. This means that these consumers may choose to buy electricity from

i. the wholesale market as a market participant;
ii. a licensed retailer ; or
iii. the MSSL (SP Services Limited)

The diagram in Figure 13 shows the contestable consumers possibly buying electricity from any of the three sellers.

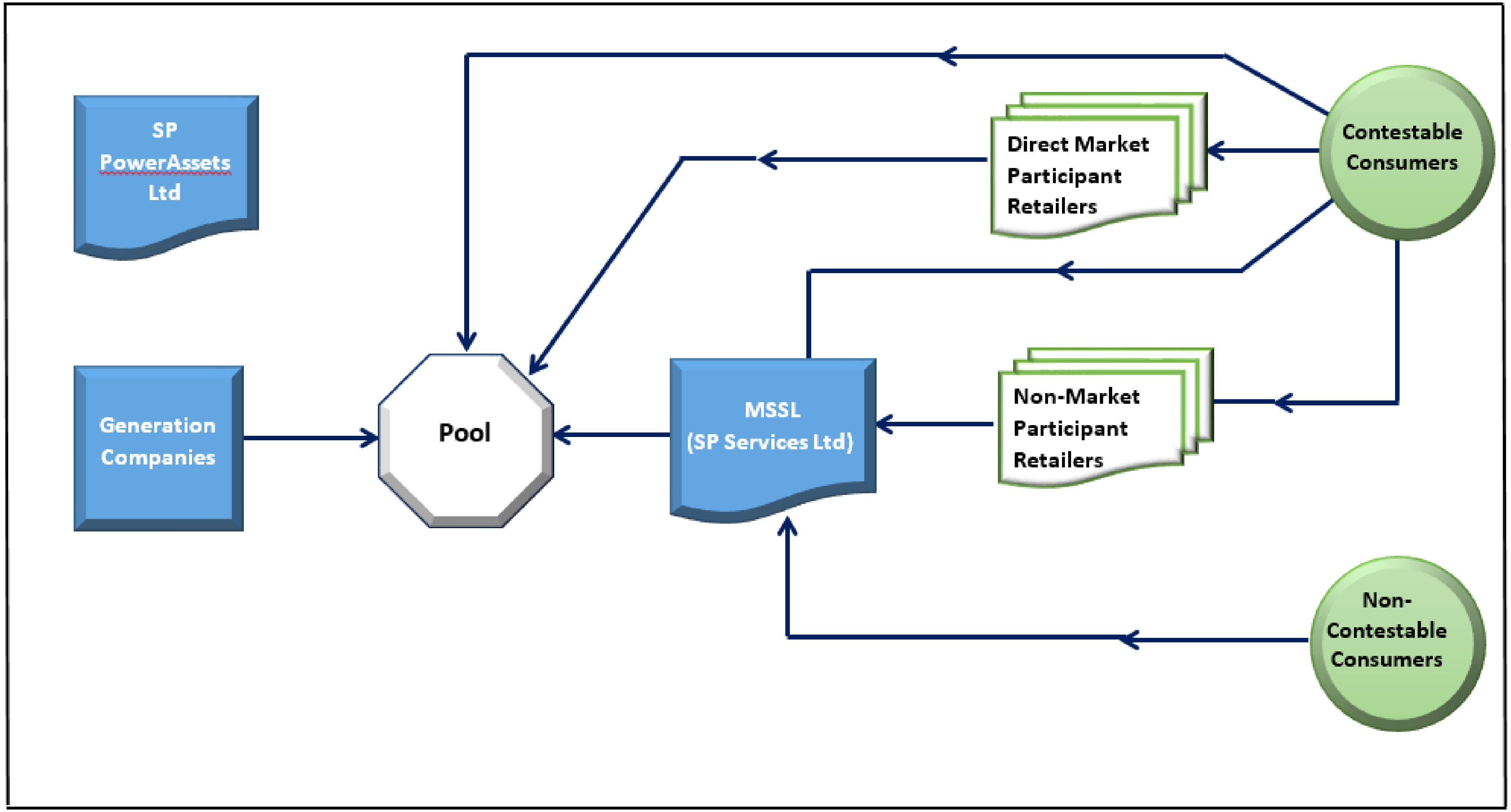

Figure 13: The National Electricity Market of Singapore

The contestable consumers who choose to buy electricity directly from the wholesale electricity market are known as direct market consumers (DMC). To be a DMC, the consumer will need to register with the Energy Market Company (EMC) and satisfy certain financial, technical and operational requirements. DMCs can only buy electricity for their own consumption and are not allowed to resell the electricity to other consumers.

Alternatively, contestable consumers may choose to buy from a licensed retailer. If the consumer buys from the wholesale electricity market, the prices fluctuate every half-hour. In contrast, the electricity price is typically fixed for a period of one (1) to three (3) years in a customised package offered by a retailer. Energy companies have to compete to gain market share by offering a pricing package that best suits the consumers' needs.

Below is a list of active retailers:

i. Keppel Electric
ii. Sembcorp Power
iii. Senoko Energy Supply
iv. Seraya Energy
v. Tuas Power Supply

The eligible consumers may choose to stay as non-contestable consumers and continue to buy electricity from MSSL (SP Services Limited) at the regulated tariff. It is not compulsory for an eligible consumer to switch to become a contestable consumer.

Thus, depending on the consumers' appetite for risks, contestable consumers have the flexibility to better manage their energy cost by purchasing from the wholesale market, an electricity retailer or continue to buy at the regulated tariff from SP Services Limited.

Non-Contestable Consumers

These are the low tension consumers with consumption below 2,000 kWh per month and all residential households. Non-contestable consumers can only buy electricity from SP Services at tariff rates which are revised quarterly.

It has been announced that the market authority is working to fully open the electricity retail market to competition by the second half of 2018. This will enable the remaining 1.3 million consumers, which are mainly households to have flexibility and choices in their electricity consumption.

11.3 Trading of Energy, Regulation and Reserve

The Singapore National Electricity Market consists of a wholesale market and a retail market. The Singapore Wholesale Electricity Market (SWEM) commenced on January 1, 2003 and it comprises of two markets:

i. The “real-time market” or spot market for energy, regulation and reserve; and
ii. The “procurement market” for other ancillary services

In a competitive market a generator has a number of objectives when setting the offers for its plant. It is signalling for example:

i. whether or not it wants to “commit” its plant to generate,
ii. at what price it is willing to start or stop its plant and offer increased output beyond that, and
iii. whether it wants to attempt to capture peak load at a high price by withholding capacity until the price reaches a certain limit.

In the spot market, buyers and sellers trade in energy, reserve and regulation through the EMC. In the “procurement market”, the EMC procures by contract, on behalf of the PSO, ancillary services required to maintain the secure operation of the power system. The real-time market uses a form of auction pricing to settle transactions in the market. This encourages the economically efficient scheduling of generation facilities in the short term, and provides incentives for new power system investment in the long term. The market is designed to be robust, transparent, equitable and cost-effective to run.

The spot market will determine every half-hourly the:

i. Dispatch quantity that each generation facility is to produce
ii. Reserve and regulation capacity required to be maintained by each facility; and
iii. The corresponding wholesale spot market prices for energy, reserve and regulation.

These quantities and prices are based on price-quantity offers made by generators and load forecasts prepared by the EMC based on demand forecast information received from the PSO.

The design principles of the SWEM are

i. Robustness

The market must perform reliably and consistently under a wide range of operating conditions

ii. Transparency

Market participants and external observers must be able to see how the market operates, so that they can be certain that the market outcomes are appropriate

iii. Equity and Fairness

The market must provide a "level playing field", offering equal and open access for all parties who wish to participate in it and that meet the requirements for wholesale market participation

iv. Minimise Transaction Costs

Unnecessary transaction costs are avoided

Generators make offers to supply energy reserve and regulation for each of their units in each half-hourly dispatch period in which they want to operate. Some consumers can offer to have their load interrupted during times of system supply shortage. Such interruptible loads are similarly permitted to offer to supply reserve. We will take a closer look at interruptible load later in this section. In the case of generators, offers for reserve can only be made in association with a corresponding offer for energy and offers can vary for each half-hour. They are assumed to stand, unless modified, from the time they are made through to dispatch.

"Regulation" is generation capacity that is able to follow the normal variations in load during the half-hour dispatch period. This is required to cover second-to-second variations in load away from estimated load and is a normal operational requirement.

"Reserve" is generation capacity that is required in case of an unexpected outage of scheduled plant (i.e. generating unit failure). Because generating units may fail without warning, some reserve capacity has to be available to be provided to the system to quickly correct the imbalance and maintain system security and stability. Typically, this capacity must be able to be supplied to the market within a time frame ranging from a few seconds to a few minutes. It is often called spinning reserve to indicate that the generating unit's turbines are already operating (literally, they are spinning) and can be activated to produce energy very quickly.

In addition, reserve is divided into different classes, with each class representing a different level of reliability of reserve providers.

Primary

i. reserve capacity is made available within 8 seconds
ii. activated automatically and reconnected manually
iii. stand down by PSO

Secondary

i. reserve capacity is made available within 30 seconds
ii. activated automatically and reconnected manually
iii. stand down by PSO

Contingency

i. reserve capacity is made available within 10 minutes
ii. activated manually and reconnected manually
iii. stand down by PSO

Not all generation plants have the technical capability to provide reserve, so it has to be certified as meeting the requirements to provide reserve before it can be offered in the market. All reserve providers are assigned by the PSO to a reserve provider group for each class of reserve they provide. The quantity of reserve required by the PSO is determined by the expected size of a contingency. It is calculated dynamically taking into account the size of the largest unit generating, the stability of the unit under contingencies and the correlation of unit failure with other contingencies.

The NEMS schedules the provision of reserve and regulation simultaneously with the dispatch of energy. Since generators who make their plant available for the provision of regulation and reserve are forgoing energy production, the NEMS has reserve and regulation markets into which generators can offer capacity and for which they will be compensated. The regulation and reserve prices are common throughout Singapore but may vary according to the reserve group to which the facility belongs.

Since a facility's capacity may be available for both energy and reserve (or regulation), the Market Clearing Engine (MCE) must consider the optimal trade-off between the offers for reserve, regulation and energy. In solving the markets for each class of reserve and regulation, the MCE simultaneously finds the lowest cost solution (in terms of the offers made) that trades off between these products for the various facilities. Therefore, because a facility must be running in order to be available for reserve, it may be dispatched for energy even though its energy offer is higher than that of the marginal plant for energy. This is acceptable where there is no cheaper energy and reserve solution for the system as a whole. Reserve and regulation providers are paid by the EMC in the same way that they are paid for energy.

Interruptible Load

Traditionally, imbalances between demand and supply due to loss of generation have been restored by increasing the output of the rest of the generators in the system. However, in recent years, the imbalance may be restored by allowing load facilities to voluntarily interrupt their consumption of energy to match the reduced supply (following a contingency situation). This service is called *Interruptible Load*. Any imbalance of the demand and supply situation, as a result of a sudden loss of generation may be restored by the reduction in the consumption of energy by a load facility.

In Singapore’s wholesale electricity market, an interruptible load will be allowed to offer in all or any of the three reserve markets (i.e. primary, secondary and contingency). Providers of this service (interruptible load) therefore compete with generators to provide reserve.

The introduction of interruptible load for reserve in the Singapore wholesale electricity market is expected to provide the following benefit to consumers:

i. the security of supply will be increased as the existing reserves by generators are supplemented by reserves from load facilities. Interruptible load offers diversification in the form of reserve available since the characteristic of this type of reserve is different than the one offered by the generators;

ii. the reduction of load is an instantaneous occurrence restoring the supply and demand balance rapidly. Generators, on the other hand, steadily ramp up to restore the imbalance;

iii. there would be a downward pressure on electricity prices with increased competition of the reserve markets; and

iv. the volatility in prices is expected to be smoothen out with the availability of an additional source of reserve.

<u>Emergency Planning</u>

The PSO is responsible for developing and publishing the Singapore Electricity Emergency Plan that describes the responsibilities of each market participant (including the generation licensees, the service providers and consumers of interruptible loads) the EMC and PSO, in the event of an emergency. In order to assist the PSO in this task, each generator is required to prepare and submit to the PSO an emergency preparedness plan and other emergency preparedness-related information, as the PSO considers necessary.

A generator must ensure that it's emergency preparedness plan:

i. describes such planning, testing, information, communication and other elements as designated by the PSO,
ii. complies with such emergency planning criteria as may be designated by the PSO,
    a) complies with all relevant reliability standards,
    b) is consistent with the emergency planning and preparedness procedures established by relevant government authorities,
iii. indicates the manner in which the impact of an emergency on public health and safety will be mitigated, and
iv. indicates the manner in which the generator will minimise the cutting and expedite the restoration of critical loads and sensitive users during short or prolonged emergencies.

The PSO must also develop and publish the Singapore Power Systems Restoration Plan for restoring security of the power system following a major contingency event, or emergency. A Generator is required to prepare and submit to the PSO a "restoration plan market participant attachment" and any other power system restoration-related information as the PSO considers necessary. These attachments are combined by the PSO and form part of the overall Singapore Power Systems Restoration Plan.

Each Generator shall ensure that its restoration plan market participant attachment includes:

i. a three-year schedule of power systems restoration training activities to be conducted by the generator at its own expense,
ii. documentation detailing organisational responsibility for coordinating with the PSO power system restoration drills,

iii. a schedule for testing the generator's equipment as may be designated in the Singapore power system restoration plan, and
iv. a statement of policy and supporting documentation demonstrating how the generator will minimise the cutting of and expedition of restoration of critical loads and sensitive users under power system restoration conditions.

The primary responsibility for outage (unavailability due to maintenance or repairs) planning rests with the PSO who, once each year, forms an annual outage plan. The process of developing the outage plan requires generators to submit their outage plans, which the PSO uses to form an initial plan. The PSO will also provide feedback as to where outages planned by generators occur at times which are unacceptable. The generators can then use this information to refine their submissions and based on these revisions, the PSO determines the final outage schedule. Generators can also make submissions after the annual outage schedule is finalised, and revised outage schedules will be issued by the PSO at intervals for the remainder of the annual planning horizon. This is the first phase in the outage approval process, and generators will also need to apply for final approval closer to the actual time of the outage.

11.4 Types of Generating Cycles and Relative Efficiency

Singapore consumed some 46,000 GWh[32] of electricity in 2014 and this is projected to grow by 2% to 3% annually. Most of this was consumed by the industrial sector (43%), followed by the commerce & services-related sector (37%). Households accounted for 15% of the total electricity consumption. The total licensed generation capacity in Singapore amounted to 12,889 MW as of end-April 2015. Of these about 9,718 MW was provided by the more efficient Combined Cycle Gas Turbines, Co-Generation Plants and/or Tri-Generation Plants. This combined generating capacity[33] can meet a peak demand of about 7,000 MW. Some of the larger generators include:

i. Power Seraya with 3,100 MW capacity
   a. Steam plant (1448 MW)
   b. Co-Gen plant (1472 MW)
   c. Open Cycle Gas Turbine plant (180 MW)

ii. Senoko Energy, 3,300 MW capacity
   a. Combined cycle plants (2,807 MW)
   b. Steam Plant (493 MW)

iii. Tuas Power Generation, 2,141 MW capacity
   a. Steam plant (600 MW)
   b. Combined cycle plants (1440 MW)
   c. Co-Gen (coal-fired) plant, (101 MW)

iv. Keppel Merlimau Cogen, 1310 MW capacity;

v. Sembcorp Cogen, 785 MW capacity; and

vi. Others, 672 MW.

[32] Source : Singapore Energy Statistics 2015
[33] Source : Energy Market Authority, Singapore

There are also waste-to-energy plants generating electricity. These are:

i. Keppel Seghers, generating capacity of 22MW from incinerating 800 tons of solid waste per day;
ii. Senoko, generating capacity of 55 MW from incinerating 2,400 tons of solid waste per day; and
iii. NEA, whose two plants have a total generation capacity 178 MW.

Without any natural energy resources, Singapore is dependent on imported fossil fuel to meet the country's energy needs. In 2014, around 95%[34] of Singapore's electricity was generated with natural gas from Malaysia & Indonesia. This figure rose from 92% in 2013.

The generators in Singapore employ a combination of technologies to generate electricity. These include:

i. Combined Cycle Gas Turbine (CCGT)
   This yields the highest efficiency of 51%. As its name suggests, CCGT combines a gas-fired turbine with a steam turbine. The design uses a gas turbine to create electricity and then captures the waste heat to generate steam, which in turn drives a steam turbine, significantly increasing the system's power output without any increase in fuel.

ii. Co-Generation (Co-Gen) Plant
   Co-generation plants are those which simultaneously generate both electricity and useful heat from a common fuel source, improving the overall energy efficiency;

iii. Steam Turbine Plant
   A steam turbine whose efficiency is about 40%, generates electricity when high pressured steam is discharged at high velocity against the turbine vanes;

[34] Source : Singapore Energy Statistics 2015

iv. Open Cycle Gas Turbine (OCGT) Plant

An open cycle gas turbine plant is a gas turbine power plant in which the heat content of the exhaust gases exiting the turbine is discarded; the efficiency of OCGT is about 31%; and

v. Waste-to-Energy Plant

A waste-to-energy plant is a power plant which generates electricity from the incineration of waste

Among the generators in Singapore, the combined cycle gas turbine proved to be the most popular accounting for 62%[35] of generating capacity. The proportion of the generating capacity by each turbine type is as follows:

i. Steam turbine (31.6%)
ii. Combined cycle gas turbine (62%)
iii. Open cycle gas turbine (2.9%)
iv. Incineration and others (3.5%)

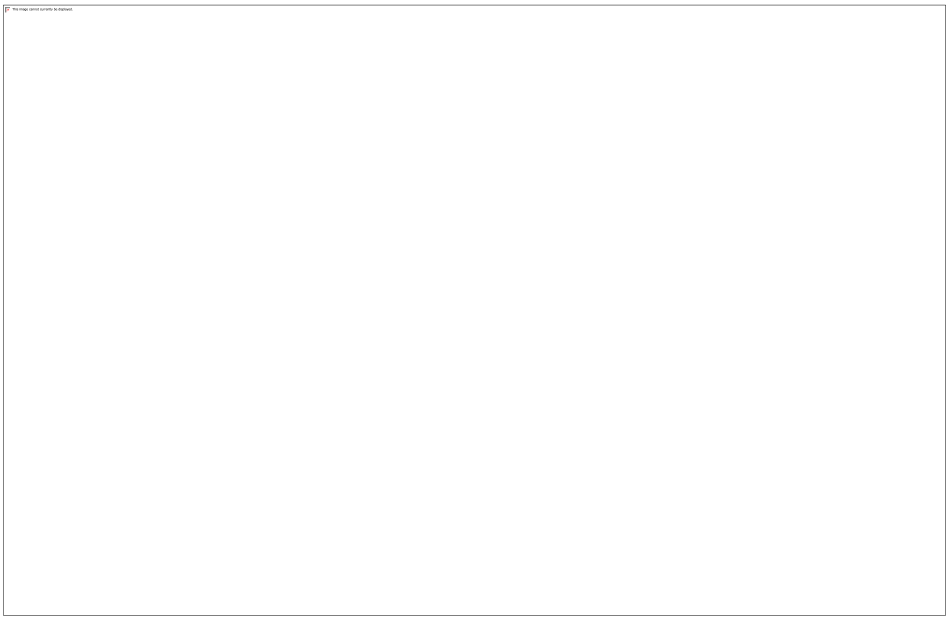

Figure 14: Licensed Generating Capacity by Technology Type

[35] Singapore Energy Statistics 2015

11.5 Electricity Cost Structure

Electricity is mostly generated at power stations by burning fossil fuels such as:

i. Coal
ii. Fuel oil
iii. Natural gas

Electricity can also be produced from renewable energy sources such as:

i. Solar
ii. Wind
iii. Hydro

The fossil fuels drive generators to produce electricity, which is then transmitted over the power grid or transmission network to consumers. Without any natural energy resources, Singapore is dependent on imported fossil fuel to meet the country's energy needs.

Over the years, Singapore's electricity generation industry moved away from oil-fired steam turbine plants by building new combined cycle gas turbine (CCGT) plants. Natural gas is used as its primary fuel, in contrast with fuel oil powered steam turbine plants. This trend combined with the increased availability of worldwide natural gas supplies through LNG imports, has resulted in the rise of natural gas' share in Singapore's electricity generation fuel mix.

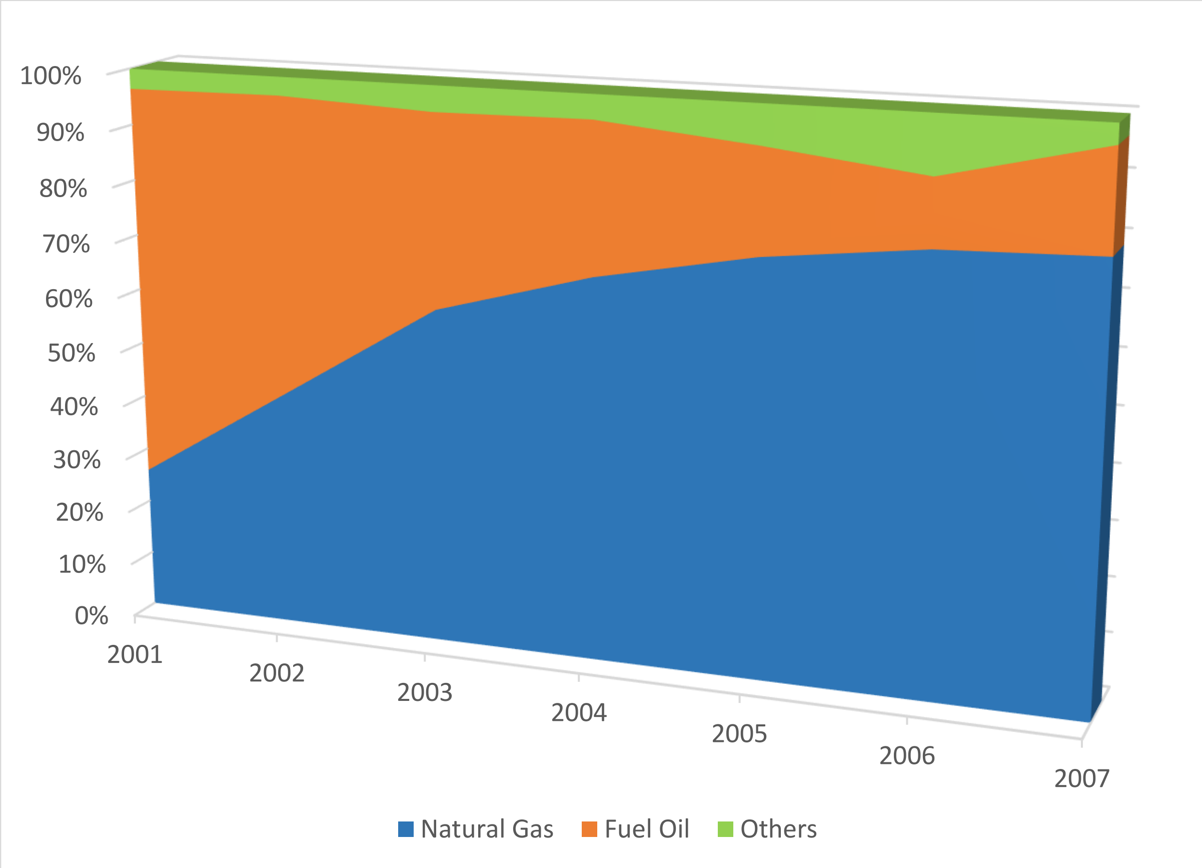

Figure 15: Fuel Mix for Electricity Generation (2001-2007)

In 2015, electricity generated in Singapore used the following energy sources[36]:

i. Natural Gas, 95% of the fuel mix in 2014, compared with 92% in 2013;
ii. Petroleum products, 0.9% , mainly in the form of diesel and fuel oil; and
iii. Others, 3.7% from municipal waste, coal and biomass

The prices of imported natural gas therefore have an impact on fuel cost for generating electricity in Singapore. However, the prices of natural gas are tied to fuel oil prices by commercial contracts. Hence, if the prices of fuel oil increase by 10%, natural gas prices would also increase by 10%. High sulphur fuel oil (HSFO) is traded globally and its price is determined by the market forces of demand and supply. The oil prices are quoted in US (United States) dollars making the exchange rate to the Singapore dollar a factor. In recent years, the Singapore dollar strengthened against the US dollar and therefore Singapore managed to moderate the wide swings in oil prices. The chart below shows the volatile fuel oil price compared to the somewhat steady electricity prices consumers pay in Singapore.

[36] Singapore Energy Statistics 2015

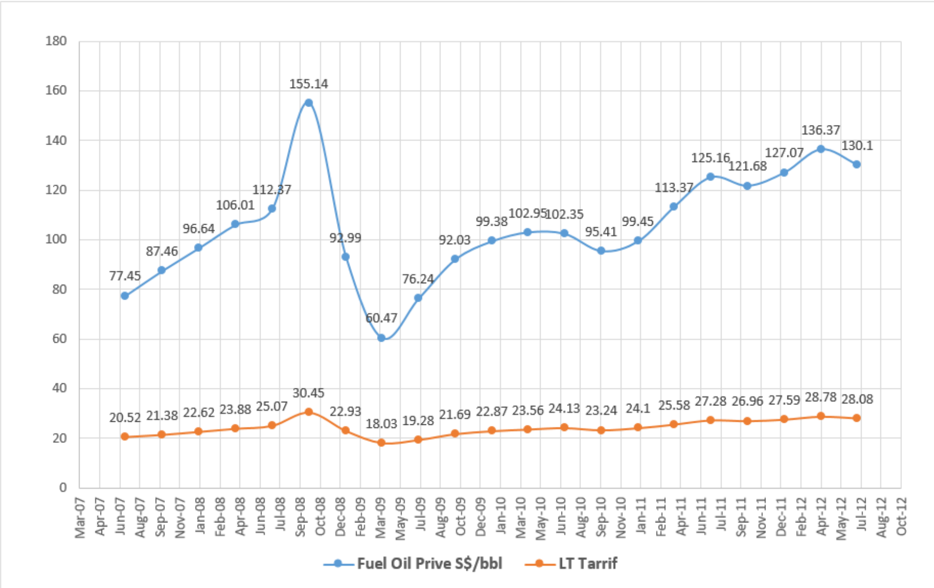

Figure 16: Fuel Oil Prices v Electricity Tariffs (low tension)[37]

It was also discussed in the earlier section that the different generating cycles yield varying efficiencies. The combined cycle gas turbine has an efficiency of 51% using much less fuel than the steam cycle which has an efficiency of 40% for power generation. This, too, directly affects the fuel component of the cost of generating electricity.

All these three factors – (a) cost of fuel oil, (b) exchange rate, and (c) the efficiency of power generator – would have an impact on the fuel cost component of the electricity tariff. To illustrate, if the calorific value of fuel is 12 MWh per metric ton (MT) and the generation efficiency is 45%, every MWh would use $\frac{1}{12}/_{0.45}$ or 0.185 MT of fuel. This follows that if the market price of fuel is US$300 per MT and the exchange rate is US$1.00 to S$1.35 , then the variable fuel cost is 0.185 x $300 x 1.35 = S$74.93 per MWh.

This pricing mechanism is discussed in section 11.9.

11.6 Wholesale Energy Price and Uniform Singapore Energy Price (USEP)

[37] Source : Singapore Energy Statistics 2015

The wholesale spot market prices reflect the cheapest market solution to the dispatch of energy and the provision of reserve and regulation. In general, this means that each generator that submitted an offer below the market price at its node will be dispatched and a generator that submitted an offer above the market price at its node will not be dispatched. The market price for energy that dispatchable generators receive is a nodal price, which may vary according to the location on the network of the node to which the dispatchable generator has been assigned. Nodal pricing differences can arise due to transmission losses, physical limitations on the transmission system, or interactions within the transmission network (loop-flow effects).

The Market Clearing Engine (MCE) calculates the dispatch schedule for energy and reserves and the associated energy and reserve prices. It automatically produces a different energy price at each node on the network, clears the market at all of the nodes simultaneously and manages the power flows between nodes to ensure a solution that is both physically feasible and economically efficient. The power flow on the transmission system is very complex and can create considerable difficulties for the management of dispatch. These complexities are handled inside the MCE and it creates a dispatch schedule that minimises the overall cost of supply to the whole system. Nodal pricing reflects the resolution of the complexities by pricing the energy at each node by ensuring that only those tranches of energy offered at, or below, the market price at their own node will be dispatched.

In the short term, by responding to the nodal prices, the market allows for the creation of a dispatch schedule that optimises the use of the transmission system. In the long term, nodal prices encourage the right investment decisions, as it is crucial to ensure that it is possible to make accurate economic evaluations of engineering decisions. Generators will build new capacity at high-price nodes, which should relieve some transmission congestion without resorting to new investment in transmission lines. When new transmission capacity is the proposed solution to congestion problems, nodal prices can help evaluate the alternatives in commercial terms. Although it is sometimes criticised as complex and unnecessary, nodal pricing adds little complexity for market participants. Rather it means that the true costs to the market of delivering electricity to each point on the transmission system are accurately represented.

In Singapore, while dispatchable generators are paid their nodal price, buyers from the wholesale market pay a uniform overall average price so that no retailers and customers are disadvantaged by their location on the network. As the Singapore transmission system is well developed, uniform pricing is an acceptable compromise between accurate economic signalling and social policy objectives.

To create a uniform price for buyers, a Uniform Singapore Energy Price or USEP is calculated from the weighted average of the nodal prices over all of the nodes that withdraw energy. The nodal energy price at each node is weighted by the energy forecast to be withdrawn from that node. In this way, the total price paid by all consumers under USEP is the same "total price that each consumer would have paid at its node".

To illustrate the bidding process that takes place every thirty (30) minutes, let's consider three generation companies (A, B, and C) offering to dispatch energy they produced. Each of the companies made four (4) bids specifying the bid price and quantity. In the figure below, these tranches (bids) are arranged in ascending order.

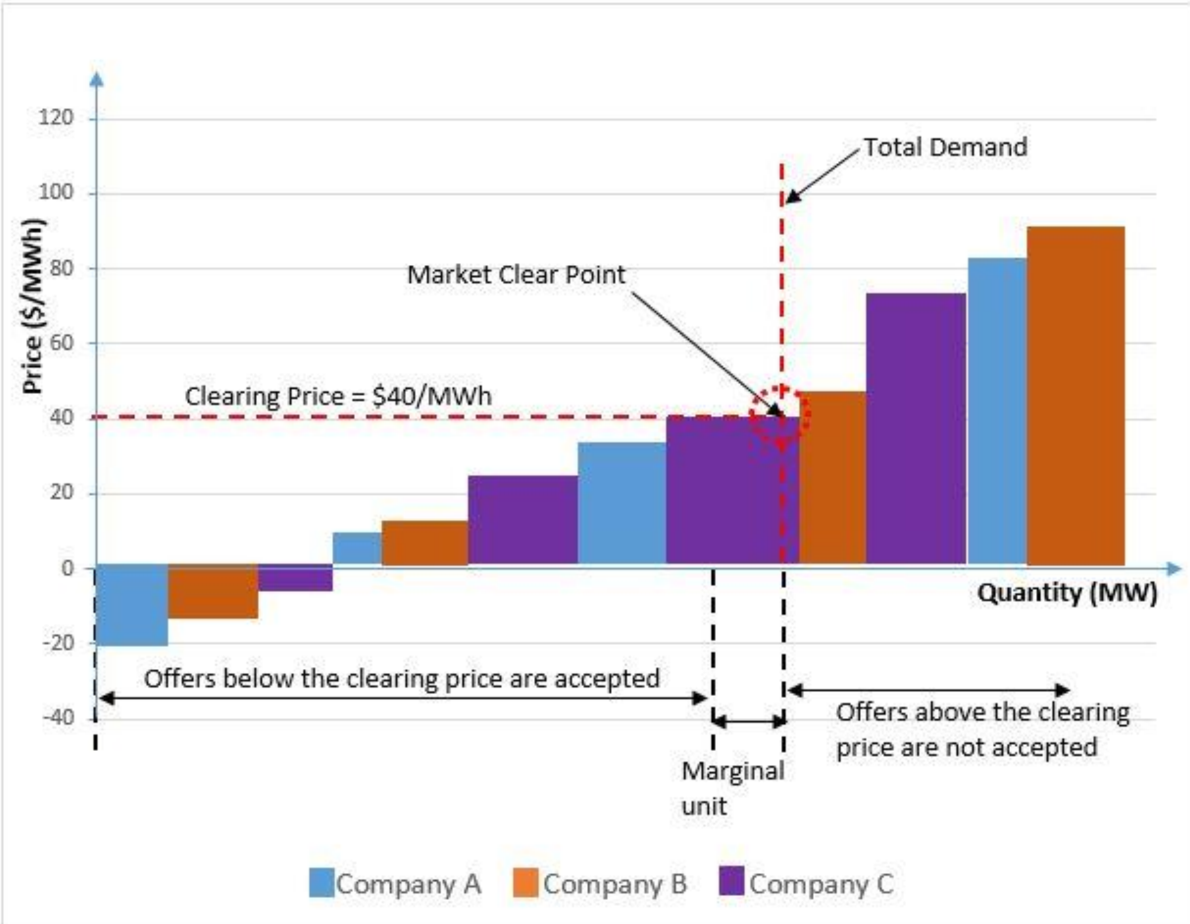

Figure 17: Market Clearing Mechanism

The Power System Operator (PSO) is responsible to make a forecast of the total demand for that period. The offer tranche that meets that demand forecast sets the market-clearing price. In this case it is the third tranche from Company C with an offer price of $40/MWh. In other words, this is when supply meets demand. If curves were drawn instead, the supply curve represents the generated capacity and the demand curve presents the predicted load. The market clearing price and dispatch schedule quantities are set by the intersection of the two curves.

Offers below the market-clearing price are accepted and those generation units are dispatched to the full. Tranches whose offers are above the market-clearing price are not accepted, and so the generation capacity represented by those offers is not dispatched at all. The third tranche which sets the market price is only partially dispatched. There is always a marginal unit whose offer sets the market-clearing price.

It is interesting that generators sometimes make negative offers. The signal the generator is giving is that the generator wants to keep its plant running over a minimum load period (typically during the middle of the night, or if the plant is a cogeneration plant) and that the cost of shutting down is greater than the cost of continuing to run. Generators may wish to continue to be dispatched through this period so that they will have capacity available as soon as load increases. It is also possible for transmission constraints on the system to cause negative prices. When it occurs, it indicates that a plant needs to be backed-off to relieve a transmission problem. The negative price provides the signal to the generator to do so. Currently, transmission constraints are unlikely to cause negative prices in the Singapore power system.

Electricity markets are very volatile. Periods of unexpected and sometimes extreme high and low prices may occur. It is not the intention, nor is it possible, that the wholesale market in Singapore eliminates or be immune to price volatility. In fact, true to the principle to let market forces of demand and supply interplay, it is important to the market that prices move freely.

The Wholesale Electricity Price (WEP) is the net purchase price paid by the retailers. It includes USEP, regulation charges, administrative charges and other charges.

WEP = USEP + AFP + HEUC + EMC & PSO fees

i. Uniform Singapore Energy Price (USEP)

This is the uniform price that is determined in the wholesale market (WEM). It is the weighted-average of the nodal prices at all off-take in each half hour.

ii. Allocated Regulation Price (AFP)

The cost of purchasing regulation products from the market is co-shared by retailers and generating companies. The AFP is determined for retailers based on their consumption (metered withdrawal quantities), and for generating companies based on their injected energy quantity, up to 5 MWh per settlement period.

iii. Hourly Energy Uplift Charges (HEUC)

This charge reconciles any differences between total amount received from retailers and total amount paid to generating companies for energy, reserve and regulation products. It is usually a negative value, i.e. a return to wholesale market purchasers.

iv. Monthly Energy Uplift Charge (MEUC)

At the end of each calendar month, EMC calculates the MEUC for the following calendar month and recovers it from the load on the basis of withdrawal quantity in MWh. This charge, levied on retailers, covers the following potential payments and receipts each month:

a. Cost of procuring contracted ancillary services (e.g. black-start services) and related costs;
b. Compensation claims and financial penalties; and
c. Estimated monthly energy uplift shortfall to be recovered in the following calendar month.

v. Energy Market Company (EMC) & Power System Operator (PSO) Fees

These fees recover the approved costs for EMC and PSO to operate the WEM and the power system in each fiscal year, respectively. These fees are levied on both generation companies (gencos) and retailers based on per MWh generated or consumed. For NMPRs, the EMC and PSO fees will be included in the retail settlement uplift charge which is an item of the Market Support Services Charges.

The electricity market is very volatile and to manage the price risk, market participants, especially retailers and consumers, need to hedge against price changes. They may seek to reduce their exposure to volatile spot prices by entering into short or long term bilateral contracts that set an agreed price for a defined quantity of electricity at specified times. Many different types of financial risk management contracts are possible in the electricity market. The most common is a Contract for Difference (CfD)

Bilateral financial contracts are outside the wholesale market in the sense that they are not taken into account in the physical dispatch process (except indirectly through generator offer behaviour) nor are in any way regulated by the market rules. The facility exists, however, for the parties to the contract to settle the contracts through the EMC's settlement system.

Let's study an example of a bilateral CfD hedge between a retailer and a generator. The hedge strike price has been agreed to be \$40 per MWh. When the spot price exceeds the strike price, the generator pays the retailer the difference between the spot price and the strike price. When the spot price is less than the strike price, the retailer pays the generator the difference between the spot price and the strike price. The net effect is that both the retailer and the generator effectively see a price of \$40 per MWh for the volume of energy covered by this hedge contract (assume 500 MWh each hour) – thereby limiting the spot price risk for both parties.

If the generator only generates 400 MWh in a given hour and the retailer consumes 600 MWh in the hour and the spot market is \$80 per MWh, the financial settlement is tabulated in Table 3-1

Table 3-1: Contract for Difference CfD

Generator	Income from spot market, 400MWh x $80	$32,000
	Compensation (CfD settlement), 500 MWh x ($80-$40)	($20,000)
	Net Income	$12,000
Retailer	Payment (spot market) , 600 MWh x $80	$48,000
	Compensation (CfD settlement), 500MWh x ($80-$40)	($20,000)
	Net Payment	$28,000

Alternatively, the net effect may be analysed as follows:

Table 3-2: Contract for Difference CfD

Generator	Sold 500 MWh for $40/MWh (400 MWh generated, 100 MWh shortfall)	$20,000
	Buy shortfall from spot market, 100 MWh x $80	($ 8,000)
	Net Income	$12,000
Retailer	Pay for contracted 500MWh x $40	$20,000
	Pay for additional 100 MWh x $80 from spot market	$ 8,000
	Net Payment	$28,000

In this example, we see how a generator can control its exposure to spot market risk by offering in the market to cover its contracts. It does this by meeting its contract obligations from its own generation as long as its short-run marginal cost is below the market price.

In this case, the generator is over-hedged and has to buy high spot price to meet its hedge quantity. The retailer has hedged most of its risk and is only exposed to the spot market for 100 MWh.

Next, we discuss vesting contracts between the generators and the MSSL.

11.8 Vesting Contracts

Vesting contracts were implemented in 2004 as a regulatory instrument to mitigate the exercise of market power by the power generation companies (gencos). Vesting contracts mandate a specified amount of electricity (viz. the vesting contract level or VCL) to be hedged at a specified price (viz. the vesting contract price), which in turn removes the incentive for gencos to exercise their market power by withholding their generation capacity to push up spot prices in the wholesale electricity market. In a sense, vesting contracts are a form of bilateral contract imposed (vested) on the generators who had been licensed by the Energy Market Authority (EMA) before the start of National Electricity Market (NEM).

The EMA determines the vesting contract level and at the start, in 2004, the vesting contract level was set at 65% of the total electricity demand. This has been progressively reduced to 40% in 2014. More recently, the vesting contract level has been revised to:

- 30% from January 2015
- 25% from July 2015
- 20% from January 2016

The objective of the vesting contracts is to curb the exercise of market power by the larger incumbent generators. The MSSL is the counterparty to all of the vesting contracts (i.e. all vesting contracts are made between generator and MSSL), which are settled between the parties through the EMC's settlement system. New generators will not be required to enter into vesting contracts.

To illustrate, here is a simplified example.

Suppose there are two generator companies X and Y. Each has 2 MW to sell. The total demand is now 3 MW. Once company X sells its 2 MW, the consumers must buy the remaining demand of 1 MW from company Y. This situation allows company Y to set the prices for the remaining 1 MW. To better manage the market power, the two companies can be vested to sell 1 MW each. The demand for the third MW will then be met by the two companies competing and offering a price attractive to the consumers. Vesting ensures no generating company is in a position to push up the price.

Vesting contracts have a price (or strike price) which is reviewed once every two years. The review considers the long run marginal cost (LRMC) of the most efficient generation technology[38] that accounts for 25% of the system demand and the policy objective of the vesting regime. The contract price is partly indexed to the price of oil as well as being indexed to the capital costs of plant and operating costs.

The overall contract level will be set to keep the incentive to use market power within the market at an acceptable level. During peak load times it will be a smaller proportion. The average contract quantity will reduce over time as new capacity is built to mitigate the market power of incumbents.

The contract quantities for each generator are based on the generation capacity for each company. The three major generators: Tuas Power, Senoko Power and PowerSeraya are obliged to hold vesting contracts, while some of the other generators will be offered vesting contracts which they have a once-off option of accepting. The contract quantities and the strike price will be recalculated every quarter. The vesting contracts are settled between the parties through the EMC's settlement system.

The MSSL is the counterparty to all the vesting contracts. The MSSL will then distribute debits and credits associated with the contracts directly to non-contestable consumers and indirectly to contestable consumers through their respective retailers.

Vesting contract levels are calculated as a proportion of Singapore load rather than generating capacity. The quantity of each generator's capacity covered by vesting contracts depends on the proportion of their capacity to total capacity in the system. The quantity of hedges allocated to each generator under the vesting contracts will continue as long as the EMA considers that market power persists. It is expected to be at least 10-12 years before market power is substantially diluted. The vesting contract quantity will be allocated firstly to non-contestable consumers who will be 100% covered by the vesting contract. The remaining vesting contract quantity will be distributed on an equal proportion basis to all contestable consumers.

The offers a contestable customer can obtain from a Retailer need not be dependent on the vesting credits the Retailer receives for its customer base. The Retailer is not required to pass on the vesting credits it receives directly to its customers.

[38] The combined cycle gas turbine (CCGT) has the highest efficiency amongst the generation technologies currently in use

Vesting contract credit and/or debit are calculated using the following formula:

Vesting contract credit/debit = ∑ (Vesting Rate x Vested Quantity)

where:

Vesting Rate = $VCRP_{hh}$ - PRP_{hh}

Vested Quantity = $Adjusted\ Energy_{hh}$ x VHP_{hh}

$VCRP_{hh}$ is the Vesting Contract Reference Price; this is the electricity price used in the vesting settlement and is calculated by the Energy Market Company (EMC). Half-hourly $VCRP_{hh}$ measured in $/MWh can be obtained from EMC's website www.emcsg.com.

PRP_{hh} is the Payment Reference Price; this is the price consumers pay for their vested quantity of their electricity consumption. PRP_{hh} ($/MWh) can be obtained from the MSSL website. PRP_{hh} is updated every quarterly and is constant for each half-hour period in that quarter.

$Adjusted\ Energy_{hh}$ is the half-hourly electricity consumption adjusted with the transmission loss factor and can be requested from MSSL by you or your retailer on your behalf.

VHP_{hh} is the Vesting Hedge Proportion; this is the percentage of contestable consumers' electricity consumption that is covered by vesting contracts and for which consumers pay the PRP_{hh}. VHP_{hh} varies every half-hourly and is expressed as a percentage (%).

There are nine (9) VHP_{hh}, each corresponding to one segment of the three periods of Peak, Off-peak and Shoulder for Sundays and public holidays, Saturdays and weekdays. The VHP_{hh} can be obtained from the MSSL website. The VHP_{hh} is updated quarterly.

Below is an example of the *VHP_{hh}* Table:

Table 4 : VHP_{hh}

VPH (%)	Peak	Off-Peak	Shoulder
Sunday/PH	**0.00**	**24.67**	**37.31**
Weekday	**46.27**	**25.87**	**36.65**
Saturday	**46.62**	**26.14**	**37.10**

Sample Day Profile Table

Each half hour has its particular VHP_{hh}. In order to apply the correct VHP_{hh} percentage for a particular half-hour, you need to refer to the Day Profile (see Table 5).

To illustrate this, the Day Profile Table shows the applicable VHP_{hh} for each half-hour with the first half-hour (period 1) starting at 00.01am and ending at 00.30am, period 2 from 00.31am to 01.00am, etc.

To select the correct VHP_{hh} for a half-hour period, identify the correct VHP_{hh} segment from the Day Profile Table. For example for the period 10.01am to 10.30am on 1 January 2004, this corresponds to period 21 for a public holiday in the Day Profile Table. The corresponding VHP_{hh} segment for this period is "Off-Peak Sunday / Public Holiday" and the VHP_{hh} from the VHP_{hh} Table for "Off-Peak Sunday / Public Holiday" is 24.67%.

Table 5: Sample Day Profile Table

Day Profile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Sunday/PH	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak
Weekdays	Shoulder	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak
Saturday	Shoulder	Shoulder	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak
Day Profile	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Sunday/PH	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Shoulder	Shoulder
Weekdays	Off Peak	Off Peak	Shoulder	Shoulder	Shoulder	Peak	Peak	Peak	Peak	Peak	Peak	Peak
Saturday	Off Peak	Off Peak	Off Peak	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Peak	Peak	Peak
Day Profile	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Sunday/PH	Shoulder	Off Peak	Shoulder	Shoulder	Shoulder	Shoulder	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak	Off Peak
Weekdays	Peak	Peak	Peak	Peak	Peak	Peak	Peak	Peak	Peak	Peak	Peak	Peak
Saturday	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder
Day Profile	37	38	39	40	41	42	43	44	45	46	47	48
Sunday/PH	Off Peak	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Off Peak
Weekdays	Peak	Peak	Peak	Peak	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder
Saturday	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder	Shoulder

Vested Quantity

The vested quantity is calculated for the half-hour period (10.01am to 10.30am on 1 January 2004) by multiplying the Adjusted $Energy_{hh}$ of that half-hour period (10.01am to 10.30am on 1 January 2004) by VHP_{hh}.

The formula is given below:

$$\text{Vested quantity} = \text{Adjusted Energy}_{hh} \times VHP_{hh}$$

Vesting Rate

The vesting rate is calculated for the half-hour period (10.01am to 10.30am on 1 January 2004) by the following formula below:

$$\text{Vesting rate} = VCRP_{hh} - PRP_{hh}$$

Calculating the Vesting Contract Credit/Debit

The vesting contract credit/debit for each half-hour period is calculated using the formula:

Vesting contract credit/debit for one half-hour period

= Vesting rate x Vested quantity

The vesting contract credit/debit for one month (for example for January 2004) will be the sum of all the vesting contract credit/debit for all the half-hour periods for the month.

Vesting contract credit/debit for January 2004

= ∑ (Vesting rate x Vested quantity)

Typically, both $VCRP_{hh}$ and PRP_{hh} are presented as dollars per MWh ($/MWh) and so the vesting rate is also in $/MWh. However, the consumption data (and hence the vested quantity) is likely to be in kWh. The vesting rate might be converted to $ per kWh by dividing the vesting rate by 1000 before calculating the vesting contract credit/debit.

The vesting contract credit/debit may be positive or negative as a result of the calculation. A negative amount means it is a vesting contract debit and the consumer has to pay more for the vested portion. A vesting contract debit will therefore appear as a **positive** item in the bill with a positive vesting rate. Conversely, a **negative** vesting rate will result in a vesting contract credit and will appear negative in the bill, meaning there is a deduction from the amount the consumer has to pay.

An example of vesting contract credit/debit

The allocation of vesting contract credit/debit is calculated by the following formula:

$$\sum (VCRP_{hh} - PRP_{hh}) \times (Energy_{hh} \times TLF^{39} \times VHP_{hh})$$

Example

For a given half-hour period;

Energy = 5,000 kWh

TLF = 1.10

VHP = 0.50

VCRP = S$ 0.10 (per kWh)

PRP = S$ 0.08 (per kWh)

$(VCRP_{hh} - PRP_{hh}) \times (Energy_{hh} \times TLF \times VHP_{hh})$

$= (0.10 - 0.08) \times (5000 \times 1.10 \times 0.50)$

= S$55

This is a vesting contract credit; the customer receives a refund of S$55 against his/her electricity payment for this half-hour period.

Note: This appears as a negative value on the bill - it is a credit to customer.

[39] TLF : Transmission Loss Factor

11.9 Components of Utility Rates

`There are two key components to the cost of electricity, namely:

i. the fuel cost, and
ii. non-fuel cost.

The fuel cost component in the tariff is based on the average fuel oil price in the previous three months. For example, the average fuel oil price in January to June was used to set the April to June tariff (see Figure 18). This electricity tariff formula helps to smoothen out any large swings in the fuel oil markets and will lead to electricity tariffs that are reflective of prevailing market conditions. The fuel cost or the cost of imported natural gas, is tied to the price of fuel oil by commercial contracts. While Singapore's electricity is mainly generated from imported natural gas, the prices of natural gas (which are determined by commercial contracts) are indexed to fuel oil prices. This is the market practice in Asia for natural gas contracts. Hence, if the prices of fuel oil increase by 10%, natural gas prices would also increase by 10%.

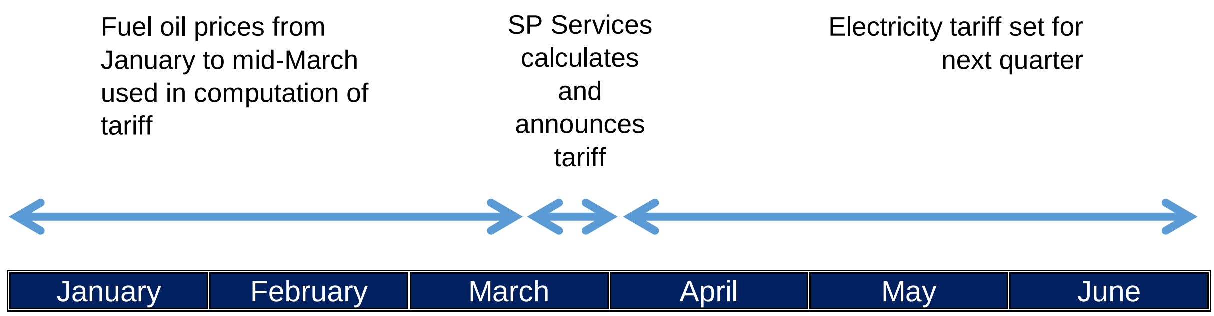

Figure 18: Formula for Electricity Tariffs

The non-fuel cost, which reflects the cost of generating and delivering electricity to our homes, has remained relatively stable over the past few years. The non-fuel cost, which reflects the cost of generating and delivering electricity to our homes, comprises the following:

a) Power Generation Cost

This mainly covers the costs of operating the power stations, such as the manpower and maintenance costs, as well as the capital costs of the stations.

b) Grid Charge

This is to recover the cost of transporting electricity through the power grid.

c) Market Support Services (MSS) Fee

This is to recover the costs of billing and meter reading.

d) Power System Operation and Market Administration Fees

These fees are to recover the costs of operating the power system and administering the wholesale electricity market.

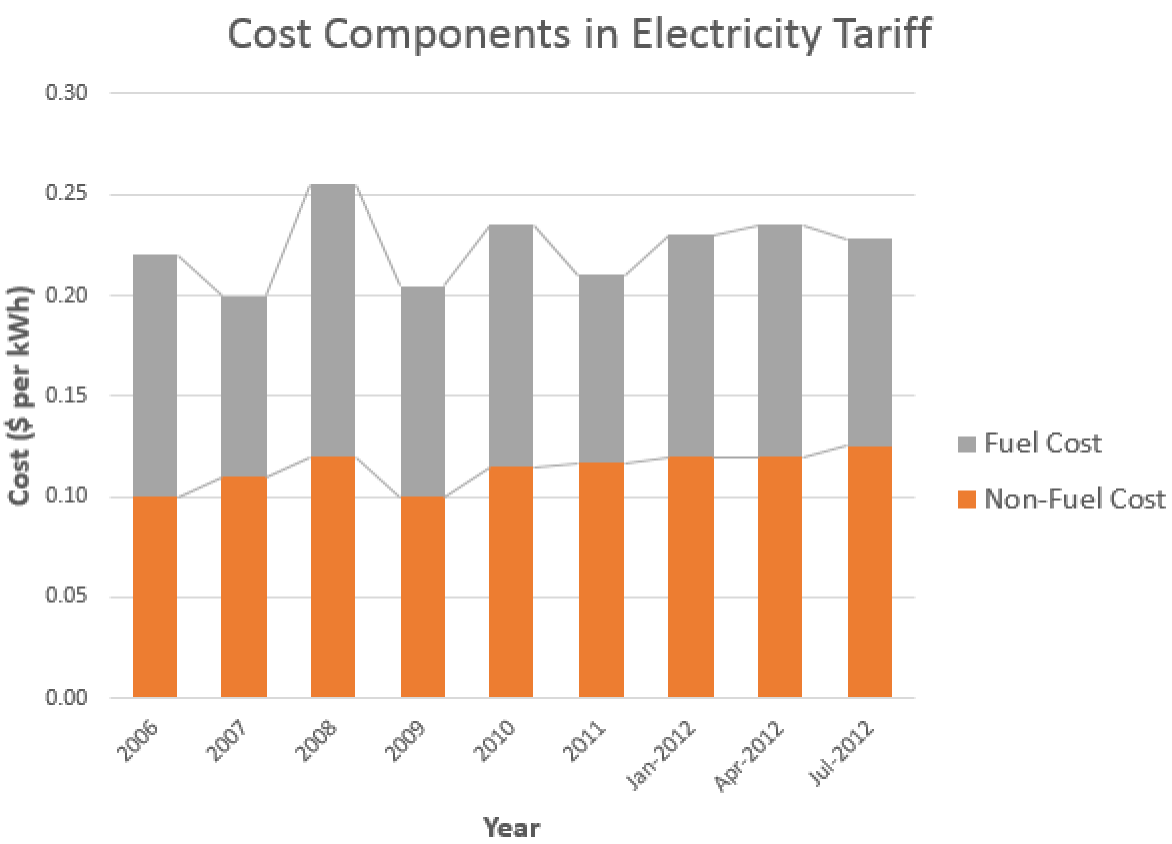

Figure 19: Cost Components in Electricity Tariff

Exercises (II)

Question 2.1

Your factory is using high tension electricity supply. You are currently buying electricity supply from SP Services. Your demand for electrical supply is quite constant throughout the 24-hour operations.

a) how do you know if your factory is a contestable consumer which means you can change the electricity retailer; who should you approach to find out?
b) how do you select a retailer ?
c) when reviewing the electricity retailer quotation, there are other costs such as a cost for *use of system* charges; what are the charges for?

Question 2.2

Which of the following is responsible for maintaining the system operations and security of electricity and transmission in Singapore

a) Power Assets
b) Power System Operator
c) Market Support Services Licensee
d) Energy Market Company

Question 2.3

Reactive power charges are paid by high tension (HT) electricity consumers if:

a) The maximum demand is below the contracted capacity
b) The maximum demand exceeded the contracted capacity
c) The power factor is lower than 0.85
d) The power factor is higher than 0.85

Question 2.4

The wholesale electricity market in Singapore is administered by

a) Power System Operator
b) Energy Market Company
c) Energy Market Authority
d) SP Services Limited

Question 2.5

Select the VHP_{hh} for the following half-hour periods,

a) January 29, 2016 (Friday) 10.31 - 11.00 am
b) February 8, 2016 (Monday) Public holiday, 2.01 to 2.30 pm

Use the VPH table below and the Day Profile Table

VHP (%)	Peak	Off-Peak	Shoulder
Sunday / PH	0.00	14.95	24.42
Weekday	33.77	15.53	22.45
Saturday	0.00	15.10	24.55

References

1. Energy Market Authority, “Introduction to Singapore New Electricity Market”, 2006

2. Singapore Energy Statistics 2015

Web Resources

1. https://www.ema.gov.sg/electricity_market_overview.aspx

2. https://www.mypower.com.sg/

Part III - Economic Analysis in Energy Efficiency Investments

12. Financial Evaluation of Energy Management Projects

12.1 Introduction and Learning Outcomes

Introduction

A common problem exists when developers or investors build a factory or a commercial building. These developers and investors tend to set their budget for the total building costs to be as low as possible. This is so they can maximise their profits on the project. Architects, engineers, and construction firms then compete to maximise their share of the fixed budget. What the developers and investors end up with are buildings that have the cheapest heating and air-conditioning systems, as opposed to the most efficient – despite the fact that a higher priced, more efficient system would save the owner money in the long haul (and is better for the environment).

The challenge for the energy manager is to convince the developers and investors to adopt a longer term perspective. In fact if the sums are done, it is a simple rational decision to be made. However, many a time a less than optimal decision is made.

Because most energy management activities are dictated by economics, the energy manager must have good financial literacy. Besides, making a technical appraisal of the energy efficiency projects, the energy manager has to assess that the project is economically viable. The viability of a project hinges on the return on investment that the project can yield. The energy manager has to determine how much funds are needed to invest in the project and how much it will cost to raise this amount of money. He has to make an assessment of the financial risk the project will bring and he weighs this against the rewards.

Learning Outcomes

At the end of this last part, the reader should be able:

1. To evaluate the financial attractiveness of energy retrofit projects
2. To understand the various energy performance contracting models

12.2. Time Value of Money

In deciding on an energy efficiency project, the bottom line question is whether the energy savings can improve the profitability of the organisation. Such financial decisions often involve situations in which someone pays money at one point in time and receives money at some later time. Dollars that are paid or received at two different points in time are different, and this difference must be recognised when analysing financial decisions and transactions. There is a time value of money. All of this is called discounted cash flow (DCF) analysis.

Revenues (or savings) and costs are calculated separately for each year over the assumed lifetime of a building, piece of equipment, or strategy. They are then discounted and summed to a specified year, usually either the first or the last year of the analysis period. The discount factor takes into account the time value of money. If all costs are referred to the first year, the discount factor for the r^{th} year is $1/(1+i)^r$, where i is the discount rate in decimal form (i.e. 6% is expressed as 0.06). If costs are referred to the last year, the discount factor for the r^{th} year is $(1+i)^{n-r}$, where n is the number of years over which the analysis extends.

Essentially, a dollar in hand today is worth more than a dollar to be received next year because, if you had it now, you could invest it, earn interest, and end up next year with more than one dollar. This may be expressed as a mathematical formula

future value (FV) = present value (PV) + interest earned in a year

$$FV = PV + PV \times i$$

$$FV = PV \times (1+ i)$$

where i is the interest rate

For example, if the present value is $100 and the interest rate, i, is 5% per annum. The future value is $105 after one year since $5 is the interest that will be earned in one year. The future value of the $100 two years from the present will be $110.25 and not just $110.

Table 6: Time Value of Money

	PV at the beginning of the year	x $(1+i)$	**FV** at the end of the year	**interest earned**
1	$100.00	1.05	$105.00	$5.00
2	$105.00	1.05	$110.25	$5.25
3	$110.25	1.05	$115.76	$5.51
4	$115.76	1.05	$121.55	$5.76
5	$121.55	1.05	$127.63	$6.08
			total	$27.63

This is because the interest earned in the second year is based on a starting value of $105; i.e. in the second year the interest earned is $105 x 5% or $5.25. In five years, the $100 will grow to a future value of $127.63. The interest earned in five years compounded to $27.63.

Conversely, since $100 would grow to $127.63 in 5 years at a 5% interest rate, $100 is the present value of $127.63 due 5 years in the future when the interest rate is 5% per annum.

The future value and present value may be expressed as mathematical formulae,

$$FV = PV \times (1+i)^n$$

$$PV = \frac{FV}{(1+i)^n}$$

where i is the interest rate , and n is the number of periods

In the context of energy efficiency proposals, monetary transactions come in the form of inflows and outflows. Suppose a heat pump costs $10,000. The heat pump will save $2,500 per year in energy costs for 7 years. The maintenance costs are $500 per year for 7 years and the salvage value is $800 at the end of the 7 years.

The inflows that can be expected are

i. savings of $2,500 per year for 7 years; and
ii. salvage value of $800 at the end of 7 years

There are also two outflows:

i. initial purchase cost of $10,000
ii. maintenance costs of $500 per year for 7 years

It is helpful to present costs visually. This can be accompanied with a tool called a cash flow diagram. Alternatively a cash flow table could be used.

A cash flow diagram is a pictorial display of the costs and revenues associated with a project. Costs are represented by arrows pointing down, while revenues are represented by arrows pointing up. Although some costs occur at different points in time, end-of-year approach is sufficient. The diagram is shown below

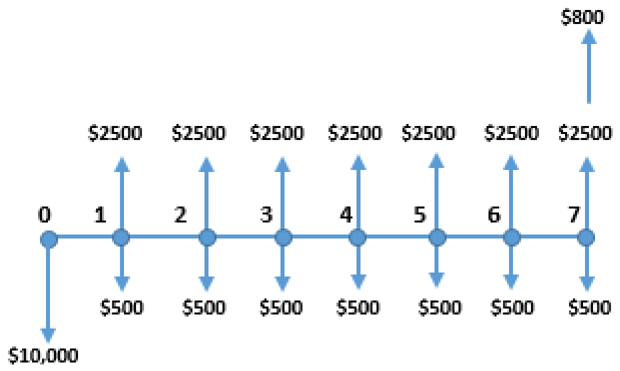

Figure 20: Cash Flow Diagram

The costs can also be listed in a tabular format as illustrated below:

Table 7: Cash Flow Table

Year	0	1	2	3	4	5	6	7
Purchase	-$10,000	--/--	--/--	--/--	--/--	--/--	--/--	--/--
Savings	--/--	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Maintenance cost	--/--	-$500	-$500	-$500	-$500	-$500	-$500	-$500
Salvage cost	--/--	--/--	--/--	--/--	--/--	--/--	--/--	+$800
Cashflow	-$10,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,800

The next step would be to find the present value of each of these future values to account for the time value of money. Applying an interest of 5%, the present value of the cashflow over the seven years is computed. This is known as the discounted cash flow.

Table 8: Discounted Cash Flow

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cashflow	**- $10,000**	**$2,000.00**	**$2,000.00**	**$2,000.00**	**$2,000.00**	**$2,000.00**	**$2,000.00**	**$2,800.00**
PV of cashflow	**- $10,000**	**$1,904.76**	**$1,814.06**	**$1,727.68**	**$1,645.40**	**$1,567.05**	**$1,492.43**	**$1,989.91**

12.3. Discount Rate

So we see that in the computations of present value, an interest rate is applied. This interest rate is sometimes known as the discount rate. This is the rate that future payouts are reduced to the present value. The term "discount" does not refer to the common meaning of the word, but to the calculation of present value.

Let's analyse a problem on this concept of time value of money and the discount rate. We shall study this concept with a situation familiar to most of us – depositing money into a bank account. Assume that it is now January 1, 2012. On January 1, 2013 you will deposit $1,000 into a savings account paying an 8% nominal interest rate.

(a) If the bank compounds interest annually, how much will you have in your account on January 1, 2016?

$1,000 is compounded for 3 years, so your balance on January 1, 2016 is $1,259.71. Using a calculator,

$$FV = PV\,(1+i)^n$$

$$= \$1{,}000\,(1.08)^3$$

$$= \$1{,}259.71$$

(b) What would your January 1, 2016 balance be if the bank used quarterly compounding rather than annual compounding?

The interest rate 8% is an annual rate. If compounded quarterly, the interest rate should be 2%, and the period of 3 years is changed to 12 quarters. Using a calculator,

$$FV = \$1{,}000\,(1.02)^{12}$$

$$= \$1{,}000\,(1.2682)$$

$$= \$1{,}268.20$$

(c) Suppose you deposited the $1,000 in 4 payments of $250 each on January 1 of 2013, 2014, 2015 and 2016. How much would you have in your account on January 1, 2016 based on 8% annual compounding?

The payment plan in this problem is similar to an annuity. This involves a sum of money paid regularly at the end of each period. The problem is more easily solved using compound interest table, (see Table 12-1) by finding the future value of an annuity of $250 for 4 years at 8 percent.

Extract from Table 12-1

Future Value of an Annuity of *$1* per period for *n* period

n	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.0100	2.0200	2.0400	2.0400	2.0500	2.0600	2.0700	2.0800	2.0900	2.1000
3	3.0301	3.0604	3.1216	3.1216	3.1525	3.1836	3.2149	3.2464	3.2781	3.3100
4	4.0604	4.1216	4.2465	4.2465	4.3101	4.3746	4.4399	4.5061	4.5731	4.6410
5	5.1010	5.2040	5.4163	5.4163	5.5256	5.6371	5.7507	5.8666	5.9847	6.1051
6	6.1520	6.3081	6.6330	6.6330	6.8019	6.9753	7.1533	7.3359	7.5233	7.7156
7	7.2135	7.4343	7.8983	7.8983	8.1420	8.3938	8.6540	8.9228	9.2004	9.4872
8	8.2857	8.5830	9.2142	9.2142	9.5491	9.8975	10.2598	10.6366	11.0285	11.4359
9	9.3685	9.7546	10.5828	10.5828	11.0266	11.4913	11.9780	12.4876	13.0210	13.5795
10	10.4622	10.9497	12.0061	12.0061	12.5779	13.1808	13.8164	14.4866	15.1929	15.9374

Future value of an annuity of $250 for 4 years at 8% p.a.

FV = annuity payment x interest rate factor

FV = PMT (FVIFA $_{k\,n}$*)*

= $250 (4.5061)

= $1,126.53

(d) Suppose you deposited 4 equal payments in your account on January 1 of 2013, 2014, 2015 and 2016. How large would each of your payments have to be with annual compounding for you to obtain the same ending balance you calculated in *Part (a)*?

FV = $1,259.71 ; i =8% ; n=4 ; PMT=?

$$FV = PMT(FVIFA_{8\%, 4\ years})$$

$$PMT\ (4.5061) = \$1{,}259.71$$

$$PMT = \$279.56$$

In the context of energy efficiency projects, consider this example. An energy efficiency proposal requires the facility owner to make six equal payments of $10,000 annually. If the facility owner is funding this project with loans from a bank which charges an interest of 5% per annum, how much would the owner have paid over six years?

The payment plan is similar to an annuity payment of $10,000 for a period of six (6) years

Amount paid per year, PMT = $10,000

Interest rate, i = 5%

Total amount to be paid over six years,

$$FV = PMT \times (FVIFA_{5\%,\ 6yrs})$$ [40]

$$= \$\ 10{,}000 \times 6.8019$$

$$= \$\ 68{,}019$$

[40] FVIFA $_{5\%,\ 6\ yrs}$ is read from Table 12-1

Table: 9-1 Interest Rate factor (PVIF)

Present Value of *$1* due at the end of *n* periods

[41] $PVIF_{i,n} = \frac{1}{(1+i)^n}$

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	0.9901	0.9804	0.9709	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174
2	0.9803	0.9612	0.9426	0.9246	0.9070	0.8900	0.8734	0.8573	0.8417
3	0.9706	0.9423	0.9151	0.8890	0.8638	0.8396	0.8163	0.7938	0.7722
4	0.9610	0.9238	0.8885	0.8548	0.8227	0.7921	0.7629	0.7350	0.7084
5	0.9515	0.9057	0.8626	0.8219	0.7835	0.7473	0.7130	0.6806	0.6499
6	0.9420	0.8880	0.8375	0.7903	0.7462	0.7050	0.6663	0.6302	0.5963
7	0.9327	0.8706	0.8131	0.7599	0.7107	0.6651	0.6227	0.5835	0.5470
8	0.9235	0.8535	0.7894	0.7307	0.6768	0.6274	0.5820	0.5403	0.5019
9	0.9143	0.8368	0.7664	0.7026	0.6446	0.5919	0.5439	0.5002	0.4604
10	0.9053	0.8203	0.7441	0.6756	0.6139	0.5584	0.5083	0.4632	0.4224
11	0.8963	0.8043	0.7224	0.6496	0.5847	0.5268	0.4751	0.4289	0.3875
12	0.8874	0.7885	0.7014	0.6246	0.5568	0.4970	0.4440	0.3971	0.3555
13	0.8787	0.7730	0.6810	0.6006	0.5303	0.4688	0.4150	0.3677	0.3262
14	0.8700	0.7579	0.6611	0.5775	0.5051	0.4423	0.3878	0.3405	0.2992
15	0.8613	0.7430	0.6419	0.5553	0.4810	0.4173	0.3624	0.3152	0.2745
16	0.8528	0.7284	0.6232	0.5339	0.4581	0.3936	0.3387	0.2919	0.2519
17	0.8444	0.7142	0.6050	0.5134	0.4363	0.3714	0.3166	0.2703	0.2311
18	0.8360	0.7002	0.5874	0.4936	0.4155	0.3503	0.2959	0.2502	0.2120
19	0.8277	0.6864	0.5703	0.4746	0.3957	0.3305	0.2765	0.2317	0.1945
20	0.8195	0.6730	0.5537	0.4564	0.3769	0.3118	0.2584	0.2145	0.1784
21	0.8114	0.6598	0.5375	0.4388	0.3589	0.2942	0.2415	0.1987	0.1637
22	0.8034	0.6468	0.5219	0.4220	0.3418	0.2775	0.2257	0.1839	0.1502
23	0.7954	0.6342	0.5067	0.4057	0.3256	0.2618	0.2109	0.1703	0.1378
24	0.7876	0.6217	0.4919	0.3901	0.3101	0.2470	0.1971	0.1577	0.1264
25	0.7798	0.6095	0.4776	0.3751	0.2953	0.2330	0.1842	0.1460	0.1160
26	0.7720	0.5976	0.4637	0.3607	0.2812	0.2198	0.1722	0.1352	0.1064
27	0.7644	0.5859	0.4502	0.3468	0.2678	0.2074	0.1609	0.1252	0.0976
28	0.7568	0.5744	0.4371	0.3335	0.2551	0.1956	0.1504	0.1159	0.0895
29	0.7493	0.5631	0.4243	0.3207	0.2429	0.1846	0.1406	0.1073	0.0822
30	0.7419	0.5521	0.4120	0.3083	0.2314	0.1741	0.1314	0.0994	0.0754

[41] Sometimes referred to as "Single Payment ($P/F_{k\%,n}$)"

Table: 9-2 Interest Rate factor (PVIF)

Present Value of *$1* due at the end of *n* periods

$$^{42}PVIF_{\ i,n} = \frac{1}{(1+i)^n}$$

	10%	11%	12%	13%	14%	15%	16%	18%	20%
1	0.9091	0.9009	0.8929	0.8850	0.8772	0.8696	0.8621	0.8475	0.8333
2	0.8264	0.8116	0.7972	0.7831	0.7695	0.7561	0.7432	0.7182	0.6944
3	0.7513	0.7312	0.7118	0.6931	0.6750	0.6575	0.6407	0.6086	0.5787
4	0.6830	0.6587	0.6355	0.6133	0.5921	0.5718	0.5523	0.5158	0.4823
5	0.6209	0.5935	0.5674	0.5428	0.5194	0.4972	0.4761	0.4371	0.4019
6	0.5645	0.5346	0.5066	0.4803	0.4556	0.4323	0.4104	0.3704	0.3349
7	0.5132	0.4817	0.4523	0.4251	0.3996	0.3759	0.3538	0.3139	0.2791
8	0.4665	0.4339	0.4039	0.3762	0.3506	0.3269	0.3050	0.2660	0.2326
9	0.4241	0.3909	0.3606	0.3329	0.3075	0.2843	0.2630	0.2255	0.1938
10	0.3855	0.3522	0.3220	0.2946	0.2697	0.2472	0.2267	0.1911	0.1615
11	0.3505	0.3173	0.2875	0.2607	0.2366	0.2149	0.1954	0.1619	0.1346
12	0.3186	0.2858	0.2567	0.2307	0.2076	0.1869	0.1685	0.1372	0.1122
13	0.2897	0.2575	0.2292	0.2042	0.1821	0.1625	0.1452	0.1163	0.0935
14	0.2633	0.2320	0.2046	0.1807	0.1597	0.1413	0.1252	0.0985	0.0779
15	0.2394	0.2090	0.1827	0.1599	0.1401	0.1229	0.1079	0.0835	0.0649
16	0.2176	0.1883	0.1631	0.1415	0.1229	0.1069	0.0930	0.0708	0.0541
17	0.1978	0.1696	0.1456	0.1252	0.1078	0.0929	0.0802	0.0600	0.0451
18	0.1799	0.1528	0.1300	0.1108	0.0946	0.0808	0.0691	0.0508	0.0376
19	0.1635	0.1377	0.1161	0.0981	0.0829	0.0703	0.0596	0.0431	0.0313
20	0.1486	0.1240	0.1037	0.0868	0.0728	0.0611	0.0514	0.0365	0.0261
21	0.1351	0.1117	0.0926	0.0768	0.0638	0.0531	0.0443	0.0309	0.0217
22	0.1228	0.1007	0.0826	0.0680	0.0560	0.0462	0.0382	0.0262	0.0181
23	0.1117	0.0907	0.0738	0.0601	0.0491	0.0402	0.0329	0.0222	0.0151
24	0.1015	0.0817	0.0659	0.0532	0.0431	0.0349	0.0284	0.0188	0.0126
25	0.0923	0.0736	0.0588	0.0471	0.0378	0.0304	0.0245	0.0160	0.0105
26	0.0839	0.0663	0.0525	0.0417	0.0331	0.0264	0.0211	0.0135	0.0087
27	0.0763	0.0597	0.0469	0.0369	0.0291	0.0230	0.0182	0.0115	0.0073
28	0.0693	0.0538	0.0419	0.0326	0.0255	0.0200	0.0157	0.0097	0.0061
29	0.0630	0.0485	0.0374	0.0289	0.0224	0.0174	0.0135	0.0082	0.0051
30	0.0573	0.0437	0.0334	0.0256	0.0196	0.0151	0.0116	0.0070	0.0042

[42] Sometimes referred to as “Single Payment (P/F *i* %,n)”

Table: 10-1 Interest Rate factor Annuity (PVIFA)

Present Value of an annuity of *$1* per period for *n* periods

$$^{43}PVIFA_{\ i,n} = \frac{1}{i} - \frac{1}{i(1+i)^n}$$

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	0.9901	0.9804	0.9709	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174
2	1.9704	1.9416	1.9135	1.8861	1.8594	1.8334	1.8080	1.7833	1.7591
3	2.9410	2.8839	2.8286	2.7751	2.7232	2.6730	2.6243	2.5771	2.5313
4	3.9020	3.8077	3.7171	3.6299	3.5460	3.4651	3.3872	3.3121	3.2397
5	4.8534	4.7135	4.5797	4.4518	4.3295	4.2124	4.1002	3.9927	3.8897
6	5.7955	5.6014	5.4172	5.2421	5.0757	4.9173	4.7665	4.6229	4.4859
7	6.7282	6.4720	6.2303	6.0021	5.7864	5.5824	5.3893	5.2064	5.0330
8	7.6517	7.3255	7.0197	6.7327	6.4632	6.2098	5.9713	5.7466	5.5348
9	8.5660	8.1622	7.7861	7.4353	7.1078	6.8017	6.5152	6.2469	5.9952
10	9.4713	8.9826	8.5302	8.1109	7.7217	7.3601	7.0236	6.7101	6.4177
11	10.3676	9.7868	9.2526	8.7605	8.3064	7.8869	7.4987	7.1390	6.8052
12	11.2551	10.5753	9.9540	9.3851	8.8633	8.3838	7.9427	7.5361	7.1607
13	12.1337	11.3484	10.6350	9.9856	9.3936	8.8527	8.3577	7.9038	7.4869
14	13.0037	12.1062	11.2961	10.5631	9.8986	9.2950	8.7455	8.2442	7.7862
15	13.8651	12.8493	11.9379	11.1184	10.3797	9.7122	9.1079	8.5595	8.0607
16	14.7179	13.5777	12.5611	11.6523	10.8378	10.1059	9.4466	8.8514	8.3126
17	15.5623	14.2919	13.1661	12.1657	11.2741	10.4773	9.7632	9.1216	8.5436
18	16.3983	14.9920	13.7535	12.6593	11.6896	10.8276	10.0591	9.3719	8.7556
19	17.2260	15.6785	14.3238	13.1339	12.0853	11.1581	10.3356	9.6036	8.9501
20	18.0456	16.3514	14.8775	13.5903	12.4622	11.4699	10.5940	9.8181	9.1285
21	18.8570	17.0112	15.4150	14.0292	12.8212	11.7641	10.8355	10.0168	9.2922
22	19.6604	17.6580	15.9369	14.4511	13.1630	12.0416	11.0612	10.2007	9.4424
23	20.4558	18.2922	16.4436	14.8568	13.4886	12.3034	11.2722	10.3711	9.5802
24	21.2434	18.9139	16.9355	15.2470	13.7986	12.5504	11.4693	10.5288	9.7066
25	22.0232	19.5235	17.4131	15.6221	14.0939	12.7834	11.6536	10.6748	9.8226
26	22.7952	20.1210	17.8768	15.9828	14.3752	13.0032	11.8258	10.8100	9.9290
27	23.5596	20.7069	18.3270	16.3296	14.6430	13.2105	11.9867	10.9352	10.0266
28	24.3164	21.2813	18.7641	16.6631	14.8981	13.4062	12.1371	11.0511	10.1161
29	25.0658	21.8444	19.1885	16.9837	15.1411	13.5907	12.2777	11.1584	10.1983
30	25.8077	22.3965	19.6004	17.2920	15.3725	13.7648	12.4090	11.2578	10.2737

[43] Sometimes referred to as "Uniform Series (P/A $_{k\%,n}$)"

Table: 10-2 Interest Rate factor Annuity (PVIFA)

Present Value of an annuity of *$1* per period for *n* periods

$$PVIFA_{\ i,n} = \frac{1}{i} - \frac{1}{i(1+i)^n}$$

	10%	11%	12%	13%	14%	15%	16%	18%	20%
1	0.9091	0.9009	0.8929	0.8850	0.8772	0.8696	0.8621	0.8475	0.8333
2	1.7355	1.7125	1.6901	1.6681	1.6467	1.6257	1.6052	1.5656	1.5278
3	2.4869	2.4437	2.4018	2.3612	2.3216	2.2832	2.2459	2.1743	2.1065
4	3.1699	3.1024	3.0373	2.9745	2.9137	2.8550	2.7982	2.6901	2.5887
5	3.7908	3.6959	3.6048	3.5172	3.4331	3.3522	3.2743	3.1272	2.9906
6	4.3553	4.2305	4.1114	3.9975	3.8887	3.7845	3.6847	3.4976	3.3255
7	4.8684	4.7122	4.5638	4.4226	4.2883	4.1604	4.0386	3.8115	3.6046
8	5.3349	5.1461	4.9676	4.7988	4.6389	4.4873	4.3436	4.0776	3.8372
9	5.7590	5.5370	5.3282	5.1317	4.9464	4.7716	4.6065	4.3030	4.0310
10	6.1446	5.8892	5.6502	5.4262	5.2161	5.0188	4.8332	4.4941	4.1925
11	6.4951	6.2065	5.9377	5.6869	5.4527	5.2337	5.0286	4.6560	4.3271
12	6.8137	6.4924	6.1944	5.9176	5.6603	5.4206	5.1971	4.7932	4.4392
13	7.1034	6.7499	6.4235	6.1218	5.8424	5.5831	5.3423	4.9095	4.5327
14	7.3667	6.9819	6.6282	6.3025	6.0021	5.7245	5.4675	5.0081	4.6106
15	7.6061	7.1909	6.8109	6.4624	6.1422	5.8474	5.5755	5.0916	4.6755
16	7.8237	7.3792	6.9740	6.6039	6.2651	5.9542	5.6685	5.1624	4.7296
17	8.0216	7.5488	7.1196	6.7291	6.3729	6.0472	5.7487	5.2223	4.7746
18	8.2014	7.7016	7.2497	6.8399	6.4674	6.1280	5.8178	5.2732	4.8122
19	8.3649	7.8393	7.3658	6.9380	6.5504	6.1982	5.8775	5.3162	4.8435
20	8.5136	7.9633	7.4694	7.0248	6.6231	6.2593	5.9288	5.3527	4.8696
21	8.6487	8.0751	7.5620	7.1016	6.6870	6.3125	5.9731	5.3837	4.8913
22	8.7715	8.1757	7.6446	7.1695	6.7429	6.3587	6.0113	5.4099	4.9094
23	8.8832	8.2664	7.7184	7.2297	6.7921	6.3988	6.0442	5.4321	4.9245
24	8.9847	8.3481	7.7843	7.2829	6.8351	6.4338	6.0726	5.4509	4.9371
25	9.0770	8.4217	7.8431	7.3300	6.8729	6.4641	6.0971	5.4669	4.9476
26	9.1609	8.4881	7.8957	7.3717	6.9061	6.4906	6.1182	5.4804	4.9563
27	9.2372	8.5478	7.9426	7.4086	6.9352	6.5135	6.1364	5.4919	4.9636
28	9.3066	8.6016	7.9844	7.4412	6.9607	6.5335	6.1520	5.5016	4.9697
29	9.3696	8.6501	8.0218	7.4701	6.9830	6.5509	6.1656	5.5098	4.9747
30	9.4269	8.6938	8.0552	7.4957	7.0027	6.5660	6.1772	5.5168	4.9789

Table: 11-1 Interest Rate factor (FVIF)

Future Value of *$1* due at the end of *n* periods

$$FVIF_{\ i,n} = (1+i)^n$$

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	1.0100	1.0200	1.0300	1.0400	1.0500	1.0600	1.0700	1.0800	1.0900
2	1.0201	1.0404	1.0609	1.0816	1.1025	1.1236	1.1449	1.1664	1.1881
3	1.0303	1.0612	1.0927	1.1249	1.1576	1.1910	1.2250	1.2597	1.2950
4	1.0406	1.0824	1.1255	1.1699	1.2155	1.2625	1.3108	1.3605	1.4116
5	1.0510	1.1041	1.1593	1.2167	1.2763	1.3382	1.4026	1.4693	1.5386
6	1.0615	1.1262	1.1941	1.2653	1.3401	1.4185	1.5007	1.5869	1.6771
7	1.0721	1.1487	1.2299	1.3159	1.4071	1.5036	1.6058	1.7138	1.8280
8	1.0829	1.1717	1.2668	1.3686	1.4775	1.5938	1.7182	1.8509	1.9926
9	1.0937	1.1951	1.3048	1.4233	1.5513	1.6895	1.8385	1.9990	2.1719
10	1.1046	1.2190	1.3439	1.4802	1.6289	1.7908	1.9672	2.1589	2.3674
11	1.1157	1.2434	1.3842	1.5395	1.7103	1.8983	2.1049	2.3316	2.5804
12	1.1268	1.2682	1.4258	1.6010	1.7959	2.0122	2.2522	2.5182	2.8127
13	1.1381	1.2936	1.4685	1.6651	1.8856	2.1329	2.4098	2.7196	3.0658
14	1.1495	1.3195	1.5126	1.7317	1.9799	2.2609	2.5785	2.9372	3.3417
15	1.1610	1.3459	1.5580	1.8009	2.0789	2.3966	2.7590	3.1722	3.6425
16	1.1726	1.3728	1.6047	1.8730	2.1829	2.5404	2.9522	3.4259	3.9703
17	1.1843	1.4002	1.6528	1.9479	2.2920	2.6928	3.1588	3.7000	4.3276
18	1.1961	1.4282	1.7024	2.0258	2.4066	2.8543	3.3799	3.9960	4.7171
19	1.2081	1.4568	1.7535	2.1068	2.5270	3.0256	3.6165	4.3157	5.1417
20	1.2202	1.4859	1.8061	2.1911	2.6533	3.2071	3.8697	4.6610	5.6044
21	1.2324	1.5157	1.8603	2.2788	2.7860	3.3996	4.1406	5.0338	6.1088
22	1.2447	1.5460	1.9161	2.3699	2.9253	3.6035	4.4304	5.4365	6.6586
23	1.2572	1.5769	1.9736	2.4647	3.0715	3.8197	4.7405	5.8715	7.2579
24	1.2697	1.6084	2.0328	2.5633	3.2251	4.0489	5.0724	6.3412	7.9111
25	1.2824	1.6406	2.0938	2.6658	3.3864	4.2919	5.4274	6.8485	8.6231
26	1.2953	1.6734	2.1566	2.7725	3.5557	4.5494	5.8074	7.3964	9.3992
27	1.3082	1.7069	2.2213	2.8834	3.7335	4.8223	6.2139	7.9881	10.2451
28	1.3213	1.7410	2.2879	2.9987	3.9201	5.1117	6.6488	8.6271	11.1671
29	1.3345	1.7758	2.3566	3.1187	4.1161	5.4184	7.1143	9.3173	12.1722
30	1.3478	1.8114	2.4273	3.2434	4.3219	5.7435	7.6123	10.0627	13.2677

Table 11-2 Interest Rate factor (FVIF)

Future Value of *$1* due at the end of *n* periods

$$FVIF_{i,n} = (1+i)^n$$

	10%	11%	12%	13%	14%	15%	16%	18%	20%
1	1.1000	1.1100	1.1200	1.1300	1.1400	1.1500	1.1600	1.1800	1.2000
2	1.2100	1.2321	1.2544	1.2769	1.2996	1.3225	1.3456	1.3924	1.4400
3	1.3310	1.3676	1.4049	1.4429	1.4815	1.5209	1.5609	1.6430	1.7280
4	1.4641	1.5181	1.5735	1.6305	1.6890	1.7490	1.8106	1.9388	2.0736
5	1.6105	1.6851	1.7623	1.8424	1.9254	2.0114	2.1003	2.2878	2.4883
6	1.7716	1.8704	1.9738	2.0820	2.1950	2.3131	2.4364	2.6996	2.9860
7	1.9487	2.0762	2.2107	2.3526	2.5023	2.6600	2.8262	3.1855	3.5832
8	2.1436	2.3045	2.4760	2.6584	2.8526	3.0590	3.2784	3.7589	4.2998
9	2.3579	2.5580	2.7731	3.0040	3.2519	3.5179	3.8030	4.4355	5.1598
10	2.5937	2.8394	3.1058	3.3946	3.7072	4.0456	4.4114	5.2338	6.1917
11	2.8531	3.1518	3.4785	3.8359	4.2262	4.6524	5.1173	6.1759	7.4301
12	3.1384	3.4985	3.8960	4.3345	4.8179	5.3503	5.9360	7.2876	8.9161
13	3.4523	3.8833	4.3635	4.8980	5.4924	6.1528	6.8858	8.5994	10.6993
14	3.7975	4.3104	4.8871	5.5348	6.2613	7.0757	7.9875	10.1472	12.8392
15	4.1772	4.7846	5.4736	6.2543	7.1379	8.1371	9.2655	11.9737	15.4070
16	4.5950	5.3109	6.1304	7.0673	8.1372	9.3576	10.7480	14.1290	18.4884
17	5.0545	5.8951	6.8660	7.9861	9.2765	10.7613	12.4677	16.6722	22.1861
18	5.5599	6.5436	7.6900	9.0243	10.5752	12.3755	14.4625	19.6733	26.6233
19	6.1159	7.2633	8.6128	10.1974	12.0557	14.2318	16.7765	23.2144	31.9480
20	6.7275	8.0623	9.6463	11.5231	13.7435	16.3665	19.4608	27.3930	38.3376
21	7.4002	8.9492	10.8038	13.0211	15.6676	18.8215	22.5745	32.3238	46.0051
22	8.1403	9.9336	12.1003	14.7138	17.8610	21.6447	26.1864	38.1421	55.2061
23	8.9543	11.0263	13.5523	16.6266	20.3616	24.8915	30.3762	45.0076	66.2474
24	9.8497	12.2392	15.1786	18.7881	23.2122	28.6252	35.2364	53.1090	79.4968
25	10.8347	13.5855	17.0001	21.2305	26.4619	32.9190	40.8742	62.6686	95.3962
26	11.9182	15.0799	19.0401	23.9905	30.1666	37.8568	47.4141	73.9490	114.4755
27	13.1100	16.7386	21.3249	27.1093	34.3899	43.5353	55.0004	87.2598	137.3706
28	14.4210	18.5799	23.8839	30.6335	39.2045	50.0656	63.8004	102.9666	164.8447
29	15.8631	20.6237	26.7499	34.6158	44.6931	57.5755	74.0085	121.5005	197.8136
30	17.4494	22.8923	29.9599	39.1159	50.9502	66.2118	85.8499	143.3706	237.3763

Table: 12-1 Interest Rate factor Annuity (FVIFA)

Future Value of an annuity of *$1* per period for *n* periods

$$\text{FVIFA}_{i,\,n} = \frac{(1+i)^n - 1}{i}$$

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.0100	2.0200	2.0300	2.0400	2.0500	2.0600	2.0700	2.0800	2.0900
3	3.0301	3.0604	3.0909	3.1216	3.1525	3.1836	3.2149	3.2464	3.2781
4	4.0604	4.1216	4.1836	4.2465	4.3101	4.3746	4.4399	4.5061	4.5731
5	5.1010	5.2040	5.3091	5.4163	5.5256	5.6371	5.7507	5.8666	5.9847
6	6.1520	6.3081	6.4684	6.6330	6.8019	6.9753	7.1533	7.3359	7.5233
7	7.2135	7.4343	7.6625	7.8983	8.1420	8.3938	8.6540	8.9228	9.2004
8	8.2857	8.5830	8.8923	9.2142	9.5491	9.8975	10.2598	10.6366	11.0285
9	9.3685	9.7546	10.1591	10.5828	11.0266	11.4913	11.9780	12.4876	13.0210
10	10.4622	10.9497	11.4639	12.0061	12.5779	13.1808	13.8164	14.4866	15.1929
11	11.5668	12.1687	12.8078	13.4864	14.2068	14.9716	15.7836	16.6455	17.5603
12	12.6825	13.4121	14.1920	15.0258	15.9171	16.8699	17.8885	18.9771	20.1407
13	13.8093	14.6803	15.6178	16.6268	17.7130	18.8821	20.1406	21.4953	22.9534
14	14.9474	15.9739	17.0863	18.2919	19.5986	21.0151	22.5505	24.2149	26.0192
15	16.0969	17.2934	18.5989	20.0236	21.5786	23.2760	25.1290	27.1521	29.3609
16	17.2579	18.6393	20.1569	21.8245	23.6575	25.6725	27.8881	30.3243	33.0034
17	18.4304	20.0121	21.7616	23.6975	25.8404	28.2129	30.8402	33.7502	36.9737
18	19.6147	21.4123	23.4144	25.6454	28.1324	30.9057	33.9990	37.4502	41.3013
19	20.8109	22.8406	25.1169	27.6712	30.5390	33.7600	37.3790	41.4463	46.0185
20	22.0190	24.2974	26.8704	29.7781	33.0660	36.7856	40.9955	45.7620	51.1601
21	23.2392	25.7833	28.6765	31.9692	35.7193	39.9927	44.8652	50.4229	56.7645
22	24.4716	27.2990	30.5368	34.2480	38.5052	43.3923	49.0057	55.4568	62.8733
23	25.7163	28.8450	32.4529	36.6179	41.4305	46.9958	53.4361	60.8933	69.5319
24	26.9735	30.4219	34.4265	39.0826	44.5020	50.8156	58.1767	66.7648	76.7898
25	28.2432	32.0303	36.4593	41.6459	47.7271	54.8645	63.2490	73.1059	84.7009
26	29.5256	33.6709	38.5530	44.3117	51.1135	59.1564	68.6765	79.9544	93.3240
27	30.8209	35.3443	40.7096	47.0842	54.6691	63.7058	74.4838	87.3508	102.7231
28	32.1291	37.0512	42.9309	49.9676	58.4026	68.5281	80.6977	95.3388	112.9682
29	33.4504	38.7922	45.2189	52.9663	62.3227	73.6398	87.3465	103.9659	124.1354
30	34.7849	40.5681	47.5754	56.0849	66.4388	79.0582	94.4608	113.2832	136.3075

Table: 12-2 Interest Rate factor Annuity (FVIFA)

Future Value of an annuity of *$1* per period for *n* periods

$$\text{FVIFA}_{i,\,n} = \frac{(1+i)^n - 1}{i}$$

	10%	11%	12%	13%	14%	15%	16%	18%	20%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.1000	2.1100	2.1200	2.1300	2.1400	2.1500	2.1600	2.1800	2.2000
3	3.3100	3.3421	3.3744	3.4069	3.4396	3.4725	3.5056	3.5724	3.6400
4	4.6410	4.7097	4.7793	4.8498	4.9211	4.9934	5.0665	5.2154	5.3680
5	6.1051	6.2278	6.3528	6.4803	6.6101	6.7424	6.8771	7.1542	7.4416
6	7.7156	7.9129	8.1152	8.3227	8.5355	8.7537	8.9775	9.4420	9.9299
7	9.4872	9.7833	10.0890	10.4047	10.7305	11.0668	11.4139	12.1415	12.9159
8	11.4359	11.8594	12.2997	12.7573	13.2328	13.7268	14.2401	15.3270	16.4991
9	13.5795	14.1640	14.7757	15.4157	16.0853	16.7858	17.5185	19.0859	20.7989
10	15.9374	16.7220	17.5487	18.4197	19.3373	20.3037	21.3215	23.5213	25.9587
11	18.5312	19.5614	20.6546	21.8143	23.0445	24.3493	25.7329	28.7551	32.1504
12	21.3843	22.7132	24.1331	25.6502	27.2707	29.0017	30.8502	34.9311	39.5805
13	24.5227	26.2116	28.0291	29.9847	32.0887	34.3519	36.7862	42.2187	48.4966
14	27.9750	30.0949	32.3926	34.8827	37.5811	40.5047	43.6720	50.8180	59.1959
15	31.7725	34.4054	37.2797	40.4175	43.8424	47.5804	51.6595	60.9653	72.0351
16	35.9497	39.1899	42.7533	46.6717	50.9804	55.7175	60.9250	72.9390	87.4421
17	40.5447	44.5008	48.8837	53.7391	59.1176	65.0751	71.6730	87.0680	105.9306
18	45.5992	50.3959	55.7497	61.7251	68.3941	75.8364	84.1407	103.7403	128.1167
19	51.1591	56.9395	63.4397	70.7494	78.9692	88.2118	98.6032	123.4135	154.7400
20	57.2750	64.2028	72.0524	80.9468	91.0249	102.4436	115.3797	146.6280	186.6880
21	64.0025	72.2651	81.6987	92.4699	104.7684	118.8101	134.8405	174.0210	225.0256
22	71.4027	81.2143	92.5026	105.4910	120.4360	137.6316	157.4150	206.3448	271.0307
23	79.5430	91.1479	104.6029	120.2048	138.2970	159.2764	183.6014	244.4868	326.2369
24	88.4973	102.1742	118.1552	136.8315	158.6586	184.1678	213.9776	289.4945	392.4842
25	98.3471	114.4133	133.3339	155.6196	181.8708	212.7930	249.2140	342.6035	471.9811
26	109.1818	127.9988	150.3339	176.8501	208.3327	245.7120	290.0883	405.2721	567.3773
27	121.0999	143.0786	169.3740	200.8406	238.4993	283.5688	337.5024	479.2211	681.8528
28	134.2099	159.8173	190.6989	227.9499	272.8892	327.1041	392.5028	566.4809	819.2233
29	148.6309	178.3972	214.5828	258.5834	312.0937	377.1697	456.3032	669.4475	984.0680
30	164.4940	199.0209	241.3327	293.1992	356.7868	434.7451	530.3117	790.9480	1181.8816

Let's try a problem to determine the present value. Again, we shall first use an example familiar to most of us – depositing money into a bank account. Assume that it is now January 1, 2012 and you will need $1,000 on January 1, 2016. Your bank compounds interest at an 8% rate annually.

(a) How much must you deposit on January 1, 2013, to have a balance of $1,000 on January 1, 2016?

The fact that it's now January 1, 2012 is irrelevant to find initial deposit to accumulate $1,000.

$FV = \$1,000$

$PV = FV\,(PVIF_{8\%,\ 3yrs})$

$= \$1,000\ (0.7938)$

$= \$793.80$

The interest rate factor is taken from Table 9-1, an extract is provided below

Extract from Table 9-1 :

Present Value of *$1* due at the end of *n* periods

n	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	0.9901	0.9804	0.9709	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174	0.9091
2	0.9803	0.9612	0.9426	0.9246	0.9070	0.8900	0.8734	0.8573	0.8417	0.8264
3	0.9706	0.9423	0.9151	0.8890	0.8638	0.8396	0.8163	0.7938	0.7722	0.7513
4	0.9610	0.9238	0.8885	0.8548	0.8227	0.7921	0.7629	0.7350	0.7084	0.6830
5	0.9515	0.9057	0.8626	0.8219	0.7835	0.7473	0.7130	0.6806	0.6499	0.6209
6	0.9420	0.8880	0.8375	0.7903	0.7462	0.7050	0.6663	0.6302	0.5963	0.5645
7	0.9327	0.8706	0.8131	0.7599	0.7107	0.6651	0.6227	0.5835	0.5470	0.5132
8	0.9235	0.8535	0.7894	0.7307	0.6768	0.6274	0.5820	0.5403	0.5019	0.4665
9	0.9143	0.8368	0.7664	0.7026	0.6446	0.5919	0.5439	0.5002	0.4604	0.4241
10	0.9053	0.8203	0.7441	0.6756	0.6139	0.5584	0.5083	0.4632	0.4224	0.3855

(b) If you want to make equal payments on each January 1 from 2013 through 2016 to accumulate the $1,000, how large must each of the 4 payments be?

Referring to Table 12-1

Extract from Table 12-1
Future Value of an Annuity of *$1* per period for *n* period

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.0100	2.0200	2.0300	2.0400	2.0500	2.0600	2.0700	2.0800	2.0900
3	3.0301	3.0604	3.0909	3.1216	3.1525	3.1836	3.2149	3.2464	3.2781
4	4.0604	4.1216	4.1836	4.2465	4.3101	4.3746	4.4399	4.5061	4.5731
5	5.1010	5.2040	5.3091	5.4163	5.5256	5.6371	5.7507	5.8666	5.9847
6	6.1520	6.3081	6.4684	6.6330	6.8019	6.9753	7.1533	7.3359	7.5233
7	7.2135	7.4343	7.6625	7.8983	8.1420	8.3938	8.6540	8.9228	9.2004
8	8.2857	8.5830	8.8923	9.2142	9.5491	9.8975	10.2598	10.6366	11.0285
9	9.3685	9.7546	10.1591	10.5828	11.0266	11.4913	11.9780	12.4876	13.0210
10	10.4622	10.9497	11.4639	12.0061	12.5779	13.1808	13.8164	14.4866	15.1929

FV = $1,000 ; n=4 years ; *i* =8% ; PMT=?

$FV = PMT\ (FVIFA_{8\%,\ 4\ yrs})$

$1,000 = PMT (4.5061)

Payment, PMT = $ 221.92

c) Which would you choose - making the four payments calculated in Part b ($221.92) or to make a lump sum payment of $750 on January 1, 2013?

The question is whether depositing $750 on January 1, 2013 and earning 8% interest per annum, would you have $1,000 on January 1, 2016?

This may be calculated using a calculator

$FV = PV\ (1+ i)^n$

$FV = \$750 \times (1+0.08)^3$

$= \$\ 944.78$

You can also use the compound interest table

$FV = PV\ (FVIF_{8\%,\ 3yrs})$

$= \$750\ (1.2597)$

$= \$944.78$

Extract from Table 11-1
Future Value of *$1* due at the end of *n* periods

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	1.0100	1.0200	1.0300	1.0400	1.0500	1.0600	1.0700	1.0800	1.0900
2	1.0201	1.0404	1.0609	1.0816	1.1025	1.1236	1.1449	1.1664	1.1881
3	1.0303	1.0612	1.0927	1.1249	1.1576	1.1910	1.2250	1.2597	1.2950
4	1.0406	1.0824	1.1255	1.1699	1.2155	1.2625	1.3108	1.3605	1.4116
5	1.0510	1.1041	1.1593	1.2167	1.2763	1.3382	1.4026	1.4693	1.5386
6	1.0615	1.1262	1.1941	1.2653	1.3401	1.4185	1.5007	1.5869	1.6771
7	1.0721	1.1487	1.2299	1.3159	1.4071	1.5036	1.6058	1.7138	1.8280
8	1.0829	1.1717	1.2668	1.3686	1.4775	1.5938	1.7182	1.8509	1.9926
9	1.0937	1.1951	1.3048	1.4233	1.5513	1.6895	1.8385	1.9990	2.1719
10	1.1046	1.2190	1.3439	1.4802	1.6289	1.7908	1.9672	2.1589	2.3674

The answer to the question therefore is making a payment of $750 on January 1, 2013 would not let you achieve the target of accumulating $1,000 by January 1, 2016.

Here's another perspective, compare $750 with the PV of payments

PMT = $221.92; k=8%; n=4 ; PV=?

PV = PMT (PVIFA $_{8\%,4\ yrs}$*)*

= $221.92 (3.3121)

= $735.02 (< $750)

The initial reaction might be to make the lump sum payment. However, this would be a mistake. As we saw above, if you were to deposit the $750 on January 1, 2013, at an 8% interest rate, to be withdrawn on January 1, 2016, the compounded interest (for 3 years only) would add to a future value of only $944.78.

The problem is that when you found the $735.02 PV of the annuity, you were finding the value of the annuity on January 1, 2012.You were comparing $735.02 today with the lump sum of $750 one year from now. This is of course invalid.

What you should have done was to take the $735.02, recognise that this is the PV of an annuity as of January 1, 2012; multiply $735.02 by 1.08 to get $793.82 (the value of the annuity as of January 1, 2013). Then on comparison, the $750 lump sum (which is to be deposited on January 1, 2013) is less than $793.82. This means the $750 is not enough to eventually yield $1,000 on January 1, 2016.

Extract from Table 10-1
Present Value of an Annuity of *$1* per period for *n* periods

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	0.9901	0.9804	0.9709	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174
2	1.9704	1.9416	1.9135	1.8861	1.8594	1.8334	1.8080	1.7833	1.7591
3	2.9410	2.8839	2.8286	2.7751	2.7232	2.6730	2.6243	2.5771	2.5313
4	3.9020	3.8077	3.7171	3.6299	3.5460	3.4651	3.3872	3.3121	3.2397
5	4.8534	4.7135	4.5797	4.4518	4.3295	4.2124	4.1002	3.9927	3.8897
6	5.7955	5.6014	5.4172	5.2421	5.0757	4.9173	4.7665	4.6229	4.4859
7	6.7282	6.4720	6.2303	6.0021	5.7864	5.5824	5.3893	5.2064	5.0330
8	7.6517	7.3255	7.0197	6.7327	6.4632	6.2098	5.9713	5.7466	5.5348
9	8.5660	8.1622	7.7861	7.4353	7.1078	6.8017	6.5152	6.2469	5.9952
10	9.4713	8.9826	8.5302	8.1109	7.7217	7.3601	7.0236	6.7101	6.4177

(d) If you have only $750 on January 1, 2013, what interest rate, compounded annually, would you have to earn to have the necessary $1,000 on January 1, 2016?

$PV = \$750 \; ; \; FV = \$1{,}000 \; ; \; n = 3 \; ; \; i = ?$

$FV = PV\,(FVIF\; i_{\,,\,3yrs})$

$(FVIF\; i\,,_{\,3yrs}) \quad = FV / PV$

$= 1.333$

Referring to table 11-2, an interest rate factor FVIF value of 1.33 corresponded to a 10% p.a. interest rate (more accurately 10.0642%)

Extract from Table 11-2
Future Value of *$1* due at the end of *n* periods

	10%	11%	12%	13%	14%	15%	16%	18%	20%
1	1.1000	1.1100	1.1200	1.1300	1.1400	1.1500	1.1600	1.1800	1.2000
2	1.2100	1.2321	1.2544	1.2769	1.2996	1.3225	1.3456	1.3924	1.4400
3	1.3310	1.3676	1.4049	1.4429	1.4815	1.5209	1.5609	1.6430	1.7280
4	1.4641	1.5181	1.5735	1.6305	1.6890	1.7490	1.8106	1.9388	2.0736
5	1.6105	1.6851	1.7623	1.8424	1.9254	2.0114	2.1003	2.2878	2.4883
6	1.7716	1.8704	1.9738	2.0820	2.1950	2.3131	2.4364	2.6996	2.9860
7	1.9487	2.0762	2.2107	2.3526	2.5023	2.6600	2.8262	3.1855	3.5832
8	2.1436	2.3045	2.4760	2.6584	2.8526	3.0590	3.2784	3.7589	4.2998
9	2.3579	2.5580	2.7731	3.0040	3.2519	3.5179	3.8030	4.4355	5.1598
10	2.5937	2.8394	3.1058	3.3946	3.7072	4.0456	4.4114	5.2338	6.1917

(e) If the payment plan is changed so that you make a single payment of $400 on January 1, 2013, and then make 6 additional payments of equal amounts each 6 months thereafter. If all of this money is deposited in a bank which pays 8 percent, compounded semi-annually, how large must your semi-annual payments be?

First, find FV of $400 on January 1, 2016

FV = PV (FVIF $_{4\%,\,6}$*)*

= $400 (1.2653)

= $506.12

You will need to accumulate an additional $493.88, being $1,000 - $506.12

FV = $493.88 ; k=4% ; n=6 ; PMT=?

PMT (FVIFA $_{4\%,6}$*) = FV*

PMT = $493.88 / (6.6330)

= $74.46

Extract from Table 12-1
Future Value of an Annuity of *$1* per period for *n* period

	1%	2%	3%	4%	5%	6%	7%	8%	9%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.0100	2.0200	2.0300	2.0400	2.0500	2.0600	2.0700	2.0800	2.0900
3	3.0301	3.0604	3.0909	3.1216	3.1525	3.1836	3.2149	3.2464	3.2781
4	4.0604	4.1216	4.1836	4.2465	4.3101	4.3746	4.4399	4.5061	4.5731
5	5.1010	5.2040	5.3091	5.4163	5.5256	5.6371	5.7507	5.8666	5.9847
6	6.1520	6.3081	6.4684	6.6330	6.8019	6.9753	7.1533	7.3359	7.5233
7	7.2135	7.4343	7.6625	7.8983	8.1420	8.3938	8.6540	8.9228	9.2004
8	8.2857	8.5830	8.8923	9.2142	9.5491	9.8975	10.2598	10.6366	11.0285
9	9.3685	9.7546	10.1591	10.5828	11.0266	11.4913	11.9780	12.4876	13.0210
10	10.4622	10.9497	11.4639	12.0061	12.5779	13.1808	13.8164	14.4866	15.1929

Consider a project that promises $40,000 savings in energy every quarter over a 7-year economic lifespan. If the facility owner funds this project with internal sources expecting 12% per annum, how much will the savings be worth today?

This is an annuity of $40,000 savings over 28 quarters; the discount rate applicable should be 3% (dividing 12% per annum by 4 quarters per year)

PMT = $40,000

i = 3%

n = 28

PV = PMT x [1](PVIFA $_{i=3\%,\ n=28\ periods}$)

PV = $40,000 x 18.7641

PV = $750,564

[1] (PVIFA $_{i=3\%,\ n=28}$) is read from Table 10-2

Next we will examine some techniques of appraising the different energy efficiency projects from an investment perspective. The concept of discounted cash flow, discussed earlier, will be applied in the analysis. There are some techniques of analysis that the energy manager should be familiar with. These are

i. Simple payback period (SPP)

ii. Net present value (NPV)

iii. Internal rate of return (IRR)

12.4. Simple Payback Period

This indicator is sometimes used to determine whether projected annual savings from operating costs warrants a particular investment cost. The estimated investment is divided by the estimated annual savings to obtain the simple payback period (in years). While this method is very straightforward, it ignores the time value of money (interest or discount rate). It should be used only for periods not exceeding three to five years. It can be modified by discounting savings occurring in future years.

- *Simple payback period* = $\frac{total\ amount\ of\ investment}{annual\ saving}$

Suppose you are considering a $100,000 investment in a project that will save $2,000 per month of energy.

The simple payback period is $\frac{\$100,000}{\$24,000}$ or 4.17 years or 50 months.

The advantage of analysing an investment using the simple payback period is the ease of doing the calculation. The payback period is expressed in very simple and easy to understand terms. A payback period of three (3) years simply means the savings will pay for the investment after three (3) years of implementing the energy efficiency project. The interest rate consideration is omitted and the different options are easily compared.

However, this method ignores the difference in the amount of savings. Consider two project proposals which have a four-year payback period. The first one saves $25,000 per year on a $100,000 investment. The second proposal saves $90,000 per year on a project costing $360,000 to implement. Here, the simple payback period seems to appraise both proposals as similar in terms of risk as both take four (4) years to recover the initial investment. There is a $65,000 per year difference in savings which has been ignored.

The simple payback period also ignores the value of the savings after the payback period. In this case, the second proposal will save a further $540,000 in the six years after the initial investment has been recovered. The first project would only save $150,000 in the same six-year period. The second proposal is markedly more attractive but the simple payback period does not give such a hint.

The earlier discussion on discounted cash flow clearly highlighted the time value of money which the simple payback period method has ignored.

12.5. Return on Investment

Related to the payback period is the concept of the *return-on-investment* (ROI) which is expressed as an interest rate,

$$ROI = \frac{annual\ saving}{total\ amount\ of\ investment}$$

Using the same example, an investment of $100,000 in an energy efficiency project will save $2,000 a month. The annual savings would then be $24,000. The R-O-I is then computed as follows

$$ROI = \frac{\$24{,}000}{\$100{,}000} = 24\%$$

12.6. Net Present Value

The Net Present Value (NPV) is the difference between the present value of revenues and the present value of costs. It is the sum of all annual discounted cash flows referred to the first year of the analysis. The higher the NPV the more desirable a project, subject to the initial cash limitations of the investor.

$$\text{NPV} = \sum_{i=1}^{n} \text{year i (net cash flow x } \frac{1}{(1+r)^n}\text{) - total investment}$$

Consider an investment of $500,000 which would save energy and operating costs worth $90,000 per year over a ten-year economic life. For a 6% p.a. interest rate, the NPV is computed as follows:

PV of investment = ($500,000.00)

PV of savings = PMT x PVIFA $_{6\%,10\ \text{years}}$

= $90,000 x 7.3601

= $662,407.83

NPV $_{(6\%,10\ \text{years})}$ = $662,407.83 - $500,000.00

= $162,407.83

This is markedly a more complicated analysis compared to the simple payback period. The amount of savings is considered when comparing alternative projects. Also, the economic lifespan of the investment is taken into account and not just the period when the initial investment is recovered from savings. Since the time value of money is taken into account, there is a need to apply the correct discount rate (or interest rate) in the computation.

The discount rate is a company-specific value which must be supplied by the company finance department. This value is usually the rate the company uses for evaluating all investments. The magnitude of the discount rate depends on the source of capital which will be used to finance the project. The company could either borrow (debt capital) from a bank or finance company or use company funds (equity capital). Borrowings from financial institutions will attract a borrowing cost, interest paid to the banks. Using company's internal funds, an opportunity cost has to be considered.

Here, the recommended rate would be the *"weighted average cost of capital" (WACC).* Suppose a company intends to finance a project to improve the energy efficiency of a system using two sources of funds; say, 60% using a loan from a bank charging 6% interest and another 40% using internal funds which has an opportunity cost of 12%. The WACC may be computed as follows

$$WACC \quad = \frac{0.6 \text{ x } 6\% + \ 0.4 \text{ x}12\%}{100\%}$$

$$= 8.4\% \ p.a.$$

This is the discount rate (interest rate) that would be used in the NPV computation.

12.7. Internal Rate of Return

The Internal Rate of Return (IRR) is the discount rate that makes the NPV equal to zero. It is obtained by iterative calculations once the cash flow stream has been identified. In other words, the IRR is calculated by a trial and error process. Thankfully a financial calculator with the IRR function pre-programmed with the Newton's algorithm will determine the value in a short time. Because IRR is expressed as a percentage, it is intuitively easy to communicate to a broad variety of clients. An investor may have a hurdle rate, which is the minimum attractive rate of return (MARR) for a project as determined by management. If the IRR is higher than the MARR, the project will be undertaken; if it is not, the investor will balk.

$$\textit{Total Investment} = \sum_{i=1}^{n} \text{year i (net cash flow x } \frac{1}{(1+r)^n}\text{)}$$

Using the same example of an investment of $500,000 which would save energy and operating costs worth $90,000 per year over a ten-year economic life. The IRR is computed to be 12.41%. If this rate is applied to the NPV computation, the NPV equals zero. In theory, any project with an IRR greater than its weighted average cost of capital is a profitable one, and therefore it is in the organisation's interest to undertake such projects. One disadvantage of the IRR though is that it is difficult to appraise a project if the cash flow changes directions more than once over the economic lifespan of the investment. Otherwise, the IRR is easily compared to interest rates.

<u>NPV vs IRR</u>

Consider this proposal, an initial investment of $100,000 will result in savings in net energy costs of $19,000 per year for a period of eight (8) years. We can plot the relationship between NPV and the discount rate for analysis. In the graph below, the discount rate is on the X-axis and the net present value (NPV) on the Y-axis.

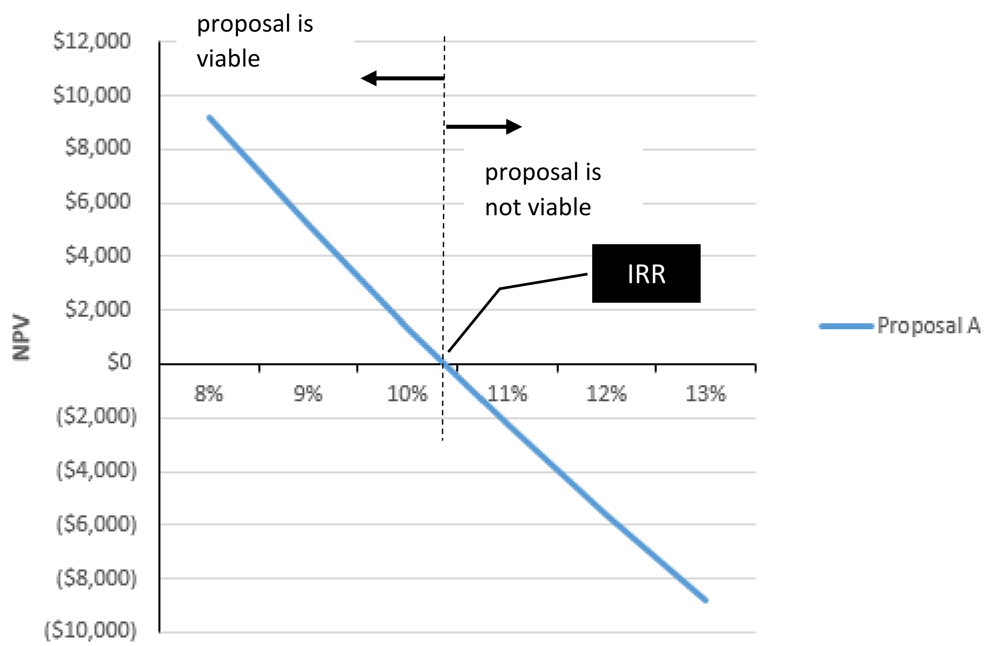

Figure 21: Graphical Representation of NPV

Quite clearly the graph shows the net present value of the proposal reducing as the discount rate rises. At one point the NPV falls to zero. This occurs at the intercept on the X-axis where NPV equals zero (NPV=0). The discount rate at the intercept is the internal rate of return (IRR) of the proposal. In this case the IRR is 10.37%. The proposal is viable when the net present value is above zero. When the discount rate is greater than the IRR, the NPV is negative and the project is considered not viable.

Very often the energy manager is considering two or more proposals at the same time. The graph below shows two proposals, A and B. If the discount rate is 8%, the NPV of proposal A is higher than the NPV of proposal B. The energy manager may be tempted to pick proposal A. However, if the energy manager also analysed the IRR of the two proposals, he may have to re-consider. In this case, the IRR of proposal A (10.37%) is lower than that of proposal B (11.82%).

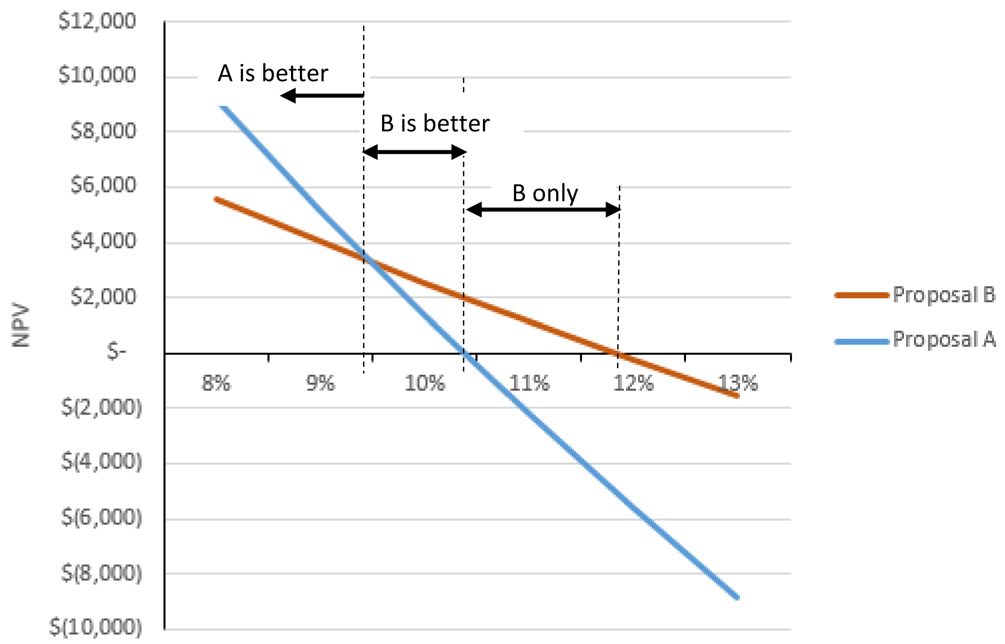

Figure 22: Graphical Representation of NPV vs IRR

Proposal A in this case is considered more sensitive to changes in the discount rate and therefore comparatively more risky. At a higher discount rate environment, proposal A may be less desirable than proposal B. In fact, should the discount rate be raised beyond 10.37%, proposal A is no longer viable while proposal B remains viable. When the discount rate goes beyond 11.82%, proposal B then becomes not viable.

Besides comparing between two or more proposals, the energy management team might be faced with changing scenarios for the same proposal. The cash flow was based on various assumptions such as a certain investment cost, energy costs, operations and maintenance costs…etc. What if these factors are changed? How sensitive is the decision dependent on any one factor?

Let's look at the example where an initial investment of $100,000 will result in savings in net energy costs of $23,000 per year for a period of eight (8) years. The internal rate of return (IRR) is 16%. This is higher than the organisation's hurdle rate of 15% and the project is then recommended. Suppose the initial investment cost is raised 5% to $105,000. The cash flow is revised and the revised IRR is 14.5%. The slight 5% change in investment cost would cause the project's IRR to fall below the hurdle rate set by the company.

Or, suppose instead the estimated energy savings fall 5% to $21,850 per year while the investment cost remained at $100,000. The revised IRR is now 14.4%. Again, the

15% hurdle rate is not crossed and the company could decide against implementing this project. The decision makers carry out such analysis to understand the risk the project is exposed to.

The project in the example is very sensitive to the cost of investment and to the estimated savings in energy. In the analysis, a rise in energy costs might result in the 5% fall in energy savings. The project has become more risky. Decision makers must then ask themselves how likely these changes will occur. The above analysis is called a “sensitivity” analysis which finds out how sensitive an output is to any change in an input while keeping other inputs constant.

12.8. Life Cycle Cost

Life Cycle Cost Analysis (LCCA) means comparing energy efficiency projects / investment proposals, based on the total cost users would pay over the entire life of the project or new equipment. This is the discounted cash flow, including initial cost, operating costs, maintenance costs, and any salvage value, usually referenced to the last year of the analysis. The project/proposal that has the lowest LCC is considered to be the best option economically.

Broadly, LCC would include:

i. Investment-related costs:
   a) Costs incurred in planning, design, purchase and construction
   b) Residual costs (salvage, disposal or resale costs)
   c) Capital replacement costs (incurred to replace major systems/equipment/components)

ii. Operational costs:
   a) Cost of operating, repairing and maintaining a system/equipment

iii. Energy costs

LCC protects decision makers from being blinded by the attraction of lower initial costs and helps to consider the operational and energy costs, which can be many times of the initial cost. In effect, LCC is a tool to assess the long-term cost effectiveness of an energy efficiency investment.

Let’s study how the life cycle cost analysis can support the decision makers to make the appropriate choice between two proposals. A pharmaceutical plant intends to replace the air-conditioning system at the warehouse. An energy audit revealed that the cooling load over a 24-hour period is 2,400 refrigeration ton – hour (RTh).

The energy manager had to choose from two options. Proposal A involved installing ten units of water-cooled packaged air-conditioning systems complete with ducts to distribute cooled air. The cost of supply and installation of this system is $800,000. Proposal B involved a central chilled water system complete with passive displacement ventilation system. This option had energy saving features but costs significantly more, at $1,500,000.

For proposal A, the water-cooled packaged air-conditioning system is estimated to have a specific energy consumption of 1.41 kW/RT. This included the consumption of the compressors, condenser water pumps and cooling tower fans. The air-side of the air-conditioning system is estimated to consume 840 kWh for a 24-hour operation.

Energy consumed by 10 water-cooled packaged units
= 2,400 RTh x 1.41 kW/RT
= 3,384 kWh

Energy consumed by fans distributing cooled air
= 840 kWh

Total energy consumption by air-conditioning system
= 3,384 + 840 KWh
= 4,224 kWh

Taking the cost of electricity at $0.20 per kWh, the energy cost of providing air-conditioning is
= 4,224 kWh per day x $0.20 per kWh
= $844.80 per day
= $308,352 per year

Considering an economic lifespan of 15 years and adjusting for an inflation rate of 3.5% per annum, the cash flow is tabulated below

Table 13-1: Energy Cost adjusted for Inflation

Proposal A : packaged air-conditioning system		
Year	Energy Cost	Energy Cost adjusted for 3.5% inflation
1	$308,352	$319,144
2	$308,352	$330,314
3	$308,352	$341,875
4	$308,352	$353,841
5[44]	$308,352	$366,225
6	$308,352	$379,043
7	$308,352	$392,310
8	$308,352	$406,041
9	$308,352	$420,252
10	$308,352	$434,961
11	$308,352	$450,185
12	$308,352	$465,941
13	$308,352	$482,249
14	$308,352	$499,128
15	$308,352	$516,597
	$4,625,280	$6,158,107

[44] FV = PV x FVIF(n=5, i=3.5%)
= $308,352 x 1.1877
= $366,225

The cost of maintaining the packaged air-conditioning system is $15,000 per year. The projected expenditure is tabulated below together with adjustment for inflation.

Table 13-2: O&M Cost adjusted for Inflation

Proposal A : packaged air-conditioning system		
Year	Operations & Maintenance (O&M) Cost	O&M Cost adjusted for 3.5% inflation
1	$15,000	$15,525
2	$15,000	$16,068
3	$15,000	$16,631
4	$15,000	$17,213
5	$15,000	$17,815
6	$15,000	$18,439
7	$15,000	$19,084
8	$15,000	$19,752
9	$15,000	$20,443
10	$15,000	$21,159
11	$15,000	$21,900
12	$15,000	$22,666
13	$15,000	$23,459
14	$15,000	$24,280
15[45]	$15,000	$25,130
	$225,000	$299,565

[45] FV = PV x FVIF(n=15, i=3.5%)
= $15,000 x 1.6753
= $25,130

To compute the life cycle costs, the present value of these costs are considered. Suppose the minimum attractive rate of return (MARR) is 12%:

Table 13-3: Present Value of Energy Costs over Expected Lifespan

Proposal A : packaged air-conditioning system		
Year	Energy Cost adjusted for 3.5% inflation	Energy Cost Present Value (MARR = 12%)
1	$319,144	$284,950
2	$330,314	$263,324
3	$341,875	$243,340
4	$353,841	$224,872
5	$366,225	$207,806
6	$379,043	$192,035
7	$392,310	$177,461
8	$406,041	$163,993
9	$420,252	$151,547
10	$434,961	$140,046
11	$450,185	$129,417
12	$465,941	$119,595
13	$482,249	$110,519
14	$499,128	$102,131
15	$516,597	$94,380
	PV of Energy Costs	$2,605,418

Table 13-4: Present Value of O&M Costs over Expected Lifespan

Proposal A : packaged air-conditioning system		
Year	O&M Cost adjusted for 3.5% inflation	O&M Cost Present Value (MARR=12%)
1	$15,525	$13,862
2	$16,068	$12,809
3	$16,631	$11,838
4	$17,213	$10,939
5	$17,815	$10,109
6	$18,439	$9,342
7	$19,084	$8,633
8	$19,752	$7,978
9	$20,443	$7,372
10	$21,159	$6,813
11	$21,900	$6,296
12	$22,666	$5,818
13	$23,459	$5,376
14	$24,280	$4,968
15	$25,130	$4,591
	PV of O&M costs	$126,742

Proposal B involved a central chilled water system that includes state-of-the-art water-cooled chillers complete with chilled water pumps controlled using variable speed drives. The condenser water pumps and fans on the cooling towers are also controlled using variable speed controls. The specific energy consumption of the central chilled water system is 0.65 kW/RT. On the air side, a passive displacement system would be used. This system relies on natural convective forces to distribute cooled air throughout the warehouse. The system did not require any air circulation fans and therefore consumed no energy.

Using the same cooling load of 2,400 RTh, the operating cost of the proposed central chilled water system is computed below.

Energy consumed = 2,400 RTh x 0.65 kW/RT
= 1,560 kWh per day

Cost of electricity = 1,560 kWh x $0.20 per kWh
= $ 312 per day
= $ 113,880 per year

The air-side system consumed no power and the estimated maintenance costs for this system is $10,000 per year. The table below shows the cash flow of the energy and operating costs over a 15-year lifespan.

Table 13-5: Present Value of Energy Costs over Expected Lifespan

Option B : Chilled Water System		
Year	Energy Cost adjusted for 3.5% inflation	Energy Cost Present Value (MARR=12%)
1	$117,866	$105,238
2	$121,991	$97,250
3	$126,261	$89,870
4	$130,680	$83,050
5	$135,254	$76,747
6	$139,988	$70,922
7	$144,887	$65,540
8	$149,958	$60,566
9	$155,207	$55,969
10	$160,639	$51,721
11	$166,261	$47,796
12	$172,080	$44,169
13	$178,103	$40,817
14	$184,337	$37,719
15	$190,789	$34,856
	PV of Energy Cost	$962,229

Table 13-6: Present Value of O&M Costs over Expected Lifespan

Option B : Chilled Water System		
Year	O&M Cost adjusted for 3.5% inflation	O&M Cost Present Value (MARR =12%)
1	$10,350	$9,241
2	$10,712	$8,540
3	$11,087	$7,892
4	$11,475	$7,293
5	$11,877	$6,739
6	$12,293	$6,228
7	$12,723	$5,755
8	$13,168	$5,318
9	$13,629	$4,915
10	$14,106	$4,542
11	$14,600	$4,197
12	$15,111	$3,879
13	$15,640	$3,584
14	$16,187	$3,312
15	$16,753	$3,061
Present Value of O&M Costs		$84,495

The life cycle costs of each proposal may be computed by adding the three component costs. The table below shows the investment-related costs, operational costs and energy costs being added up to present the total costs the end-users would pay over the entire service life of each proposal.

Table 13-7: Life Cycle Cost Analysis

Life Cycle Cost	Proposal A	Proposal B
Investment-related Costs	$ 800,000	$ 1,500,000
Operational Costs	$ 126,742	$ 84,495
Energy Costs	$ 2,605,418	$ 962,229
Total	$ 3,532,160	$ 2,546,724

The appropriate decision would be to accept the proposal with the least life cycle costs. If the decision makers chose proposal A which had a lower initial cost of installation, they would end up paying significantly more over the 15-year life of the system. In this case, proposal A would cost $3,532,160 which is $985,436 more than proposal B in present value terms over the 15-year lifespan of the equipment. In trying to save an additional capital outlay of $700,000, advocates of proposal A would end up paying more.

Indeed, the LCC analysis helps decision makers from being blinded by the attraction of lower initial costs. The operational and energy costs, as seen in this case study, can be many times of the initial cost. The life cycle cost analysis is recommended for assessing the long-term cost effectiveness of an energy efficiency investment.

13. Introduction to Energy Performance Contracting

When evaluating proposals of energy management projects, particularly those with a significant capital cost, it is important to conduct a life-cycle cost analysis. This not only provides good information about the financial attractiveness (or otherwise) of a project, but also assures management that the project has been carefully considered and evaluated.

Whether it is the facility / building owner or a third party who raises funds to invest in the energy efficiency measures, several financing alternatives need to be considered. Capital for energy-efficiency improvements is available from various public and private sources, and can be accessed through a wide and flexible range of financing instruments. The following sources of funds may be considered:

i. internal funds, or direct allocations from an organisation’s own internal capital or operating budget;
ii. debt financing, with capital borrowed directly by an organisation from private lenders; and
iii. lease or lease-purchase agreements, in which equipment is acquired through an operating or financing lease with little or no up-front costs, and payments are made over five to ten years.

An organisation may use several of these financing mechanisms in various combinations. The most appropriate set of options depends on the type of organisation (public or private), size and complexity of a project, internal capital constraints, in-house expertise, and other factors.

Energy efficiency (EE) retrofits usually require high upfront capital and building owners may find difficulty securing the initial capital required. In the private sector, Energy Performance Contracting (EPC) is often offered by energy consulting companies, commonly known as EPC firms to overcome this barrier.

EPC addresses the scepticism of building owners whether the projected energy savings can be realised by undertaking the performance risks of a project. There are two (2) common models in an EPC - guaranteed savings and shared savings.

13.1 Guaranteed savings

Under the guaranteed savings model, the building owner arranges for his own financing of the EE retrofits and engages an EPC firm for the retrofit works. The EPC firm takes up performance risks by guaranteeing the energy savings. The building owner usually pays the EPC firm for the retrofit work in a few tranches, typically withholding the last tranche until energy savings are verified.

The energy performance contract model requires the equipment supplier or vendor and even external energy consultants to provide a guaranteed amount of savings. The vendor and/or consultant are then paid on condition the savings are achieved over a contract period.

If savings exceed expectation, the contract period may have a shortened guarantee period and the vendor or consultant is relieved of their responsibility sooner. Usually, the facility owner keeps all extra savings but depending on how the contract had been negotiated, the vendor or consultant may get a share of the extra savings.

However, if there is a shortfall in savings, the vendor or consultant may get penalised. Some contracts require energy performance contractor to compensate the facility owner for the shortfall in savings.

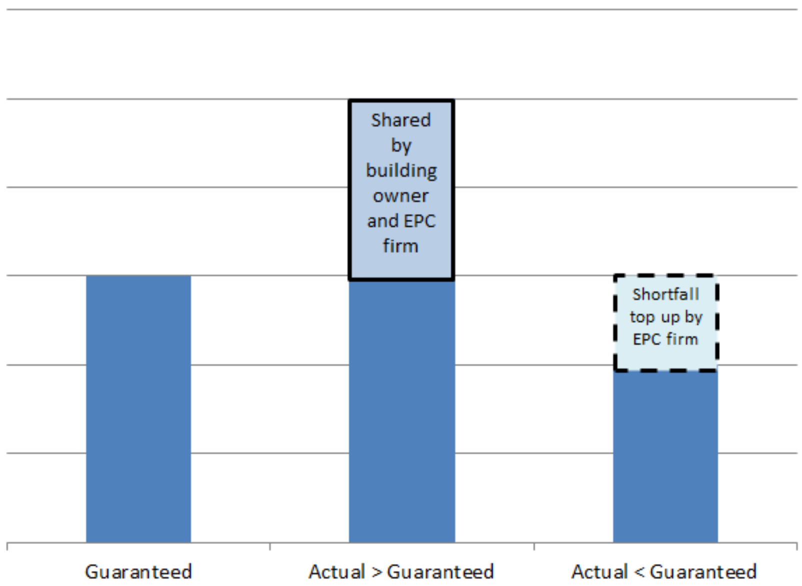

Figure 23: Guaranteed Savings

In the event of a short fall in energy savings, the EPC firm will have to pay the building owner the difference between the guaranteed and achieved savings.

Case Study No. 1

Let's study how the energy manager of a hotel group identified five of their hotel buildings and engaged a specialist contractor to design and build heat recovery systems for their provision of hot water service. The five hotels were built with gas-fired water heaters. Collectively, the 2,200 guest rooms consume about 400 to 450 m^3 of hot water every day. This requires 6.18 GWh of gas every year and cost the hotels $1,050,000 per year.

After learning from the experiences of hospitals and other hotels that have used heat recovered from the air-conditioning system to heat water, the energy manager considered this alternative heating system. A specialist contractor promoting this solution was engaged to study the feasibility of employing this technology in the five hotels.

The following actions were consequently implemented:-

i. the quality of the hot water service and the volume consumed by each hotel used were benchmarked;
ii. the profile of hourly demand for hot water service at each hotel was tracked for weekdays and for weekends;
iii. an energy audit verified that the gas-fired heaters consumed a total of 16,900 kWh of gas on a daily basis; and
iv. the realistic target of savings was set for each hotel.

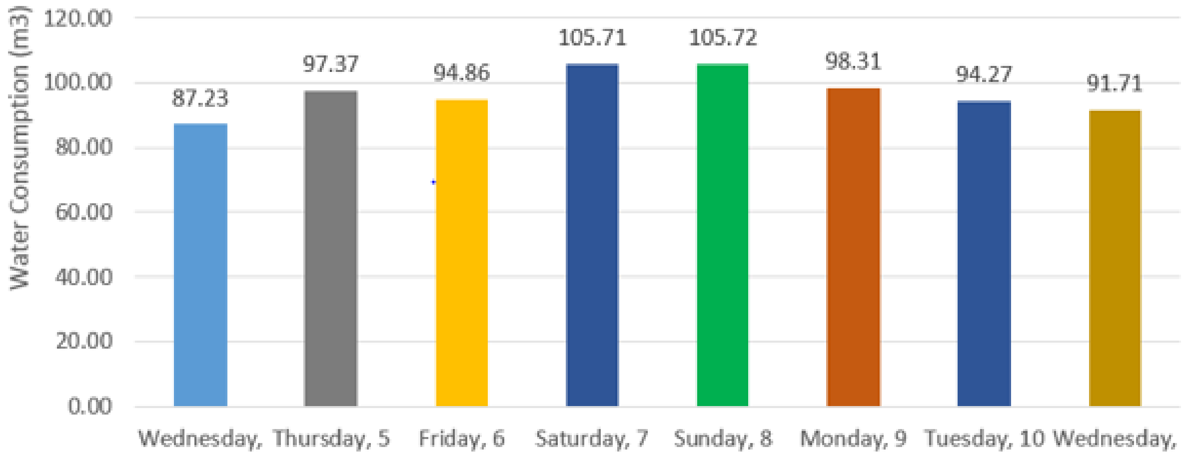

Figure 24: daily demand of hot water service (m³/day) in one hotel

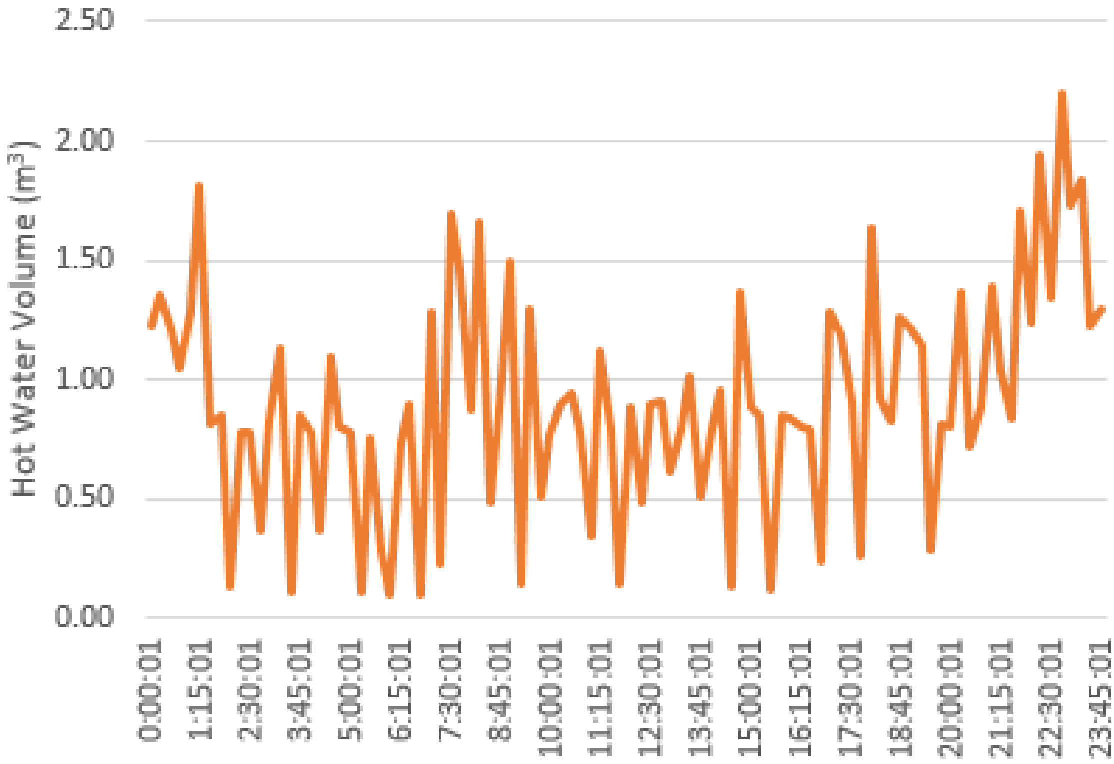

Figure 25: hourly consumption of hot water in one hotel (m³/hour)

The energy manager then studied the technical aspect of the energy efficiency proposal. He made this assessment:-

i. the heat recovery technology is easily understood, and well established;
ii. the proposed system had a safety feature that addressed the concerns of other users;
iii. the projected energy savings is substantial, in the order of 95% of the 6.18 GWh consumed yearly; and
iv. the heat recovery system may be installed quite quickly and without any disruption to the normal operations of the hotels.

Next, the energy manager studied the economics of this proposal. The specialist contractor made their assessment and was prepared to guarantee that the energy savings would be $997,500 per year. The cost of the five heat recovery systems would cost the hotel group $3,000,000. The simple payback period is easily computed to be just over three (3) years. The return on investment is attractive at 33.3% per annum.

$$\text{Return-on-Investment (ROI)} = \frac{\$997{,}500}{\$3{,}000{,}000}$$

$$= 33.3\%$$

At a 5% discount rate, the net present value (NPV) is $4.7 million and the internal rate of return is 31% which is markedly above the group's hurdle rate of a minimum attractive rate of return (MARR) of 20%.

Table 14: NPV Computation

Year	Future Value (FV) of Savings	Present Value (PV) of Savings
1	$997,500.00	$950,000.00
2	$997,500.00	$904,761.90
3[46]	$997,500.00	$861,678.00
4	$997,500.00	$820,645.72
5	$997,500.00	$781,567.35
6	$997,500.00	$744,349.86
7	$997,500.00	$708,904.63
8	$997,500.00	$675,147.26
9	$997,500.00	$642,997.39
10	$997,500.00	$612,378.47
total PV of savings at 5% p.a.		$7,702,430.59
less initial investment		$(3,000,000.00)
Net Present Value (NPV)		$4,702,430.59

When the energy manager presented the proposal to the group's top management, he was confronted with having to justify investing $3,000,000 to replace the existing heating systems which were still in good working condition. Detractors argued that the existing systems were not even past the half way mark of the expected lifespan. The average age of these existing systems was just four years old, and the newest one was just installed two years earlier. The total book value of these equipment were in excess of $4,000,000.

The energy manager argued that the decision that had to be made was between two options – 1) to postpone the investment in the proposed energy efficiency project till

[46] PV = FV x PVIF(n=3, i=5%)
= $997,500 x 0.7835
= $861,678

the existing systems are nearer the end-of-economic-life or 2) to proceed with the proposed project and writing off a substantial sum in book value.

The money spent on installing the existing systems are sunk cost which would never be recovered. If the five hotels waited till the existing equipment broke down or till the assets depreciated so that the book value was near zero, a further $6 million of gas would be consumed. Such a decision would mean adding another $5 million in present value to the operating cost of providing the hot water service.

On the other hand, the investment in the proposed heat recovery systems would payback in three years. And from the fourth year until the expected ten-year lifespan ended, there would be a further $7 million in future savings or $4.7 million present value at 5% discount rate.

The decision to proceed with the proposed project is a rational one. Economically, the value proposition of energy efficiency project is superior to the option of fretting over sunk cost. The group's management, however, needed assurance that the savings could be guaranteed at least till the three-year payback period had expired. The energy manager negotiated a deal with the specialist contractor to implement the energy efficiency project under an energy performance contract (EPC). In such arrangement the hotel group would pay for the new heat recovery systems in several tranches according to the progress of the installation. The EPC contractor would be paid the final tranche at the end of the 12-month defect liability period and be relieved of a performance guarantee after a further two years or when the investment of $3,000,000 had been paid back by the energy saved, whichever came earlier. The performance guarantee is an instrument where the EPC contractor, through its banker, provided an irrevocable guarantee that the system installed will perform as promised.

Should the energy efficiency project perform better than expected, the EPC contractor will be relieved of its responsibilities earlier. If the performance does not meet its mark, the hotel group has recourse to recover the shortfall.

13.2. Shared Savings

Under the shared savings model, EPC firm undertakes additional financing risks of the energy retrofit, in addition to the performance risks. The EPC firm provides the financing for the retrofit, either through its own equity or from bank loans. The building owner pays for the retrofit over an agreed period of time, usually through the energy savings reaped.

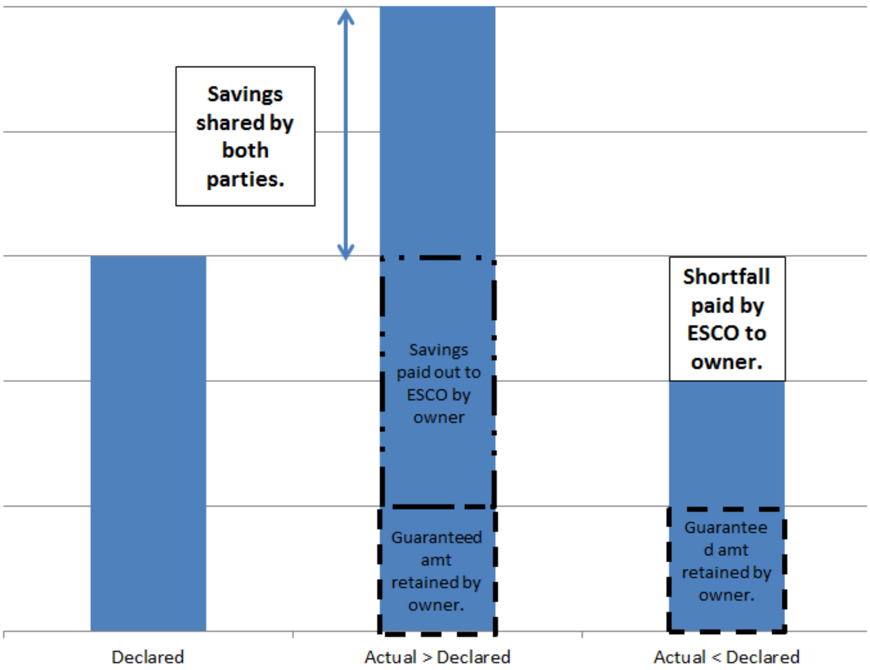

Figure 26: Shared Savings

In this arrangement, the energy performance contractor will recover its investment over a period of time. The contractor therefore assumes the risk of making a fairly accurate estimate of the savings.

Case Study No. 2

Let's study a case of a commercial building in Beach Road, Singapore where the energy efficiency project was funded by the energy consultant under the shared savings model. The energy performance contract (EPC) was negotiated directly between the building owners and the energy consultant. The latter provided the funds to implement the energy retrofit and shared the savings with the building owners using a mutually agreed formula. Although the entire energy efficiency project covered several mechanical and electrical systems including artificial lightings, only the air-conditioning system shall be discussed in this case study.

The over-35-year old building was built with a centralised air-conditioning system. Over the years the performance of the central chilled water system deteriorated under a breakdown maintenance programme. Leaking pipes did not get any prompt maintenance actions till it caused some inconvenience to occupants. At times, damaged components would remain out of service for months as long as the system continued to operate. No attention was paid to the energy performance of the chilled water system. By the early 2000s, some tenants / occupants gave up and started installing unitary units to better cool their own space. In fact, the chilled water supply in one part of the building, some 20% of the entire air-conditioned space, was completely disconnected and the space was cooled by unitary units. When a pre-retrofit energy audit was performed, it was found the existing chilled water system had a specific energy consumption of 1.52 kW/RT.

The building managers have had troubles raising funds to replace the inefficient chillers, pumps and cooling towers. The building owner was sceptical that the potential savings can indeed pay for the retrofitted plant. Furthermore, the proposal to improve the chilled water system's efficiency would require a significant capital investment.

An energy services company (ESCO) was approached to study the energy performance of this building in general, and more specifically, the central chilled water system. One of first tasks was to conduct an energy audit. It was found that the existing 500-ton chillers were bigger than were needed. The performance of the chillers were tracked and the data collected was analysed. A chart was plotted to show how often the chillers were run at any given load (see figure 26). It revealed that over 80% of the time the chillers were running at less than 55% load. In fact, the most frequently occurring load on the chiller was 250 ton (50%).

The data was also plotted to show the plant efficiency against the different operating capacities. The figure 27 below shows the central chilled water system was running at an inefficient 1.52 kW/RT. It is therefore important that the energy audit be accurately done so that an accurate estimate of the energy savings can be determined.

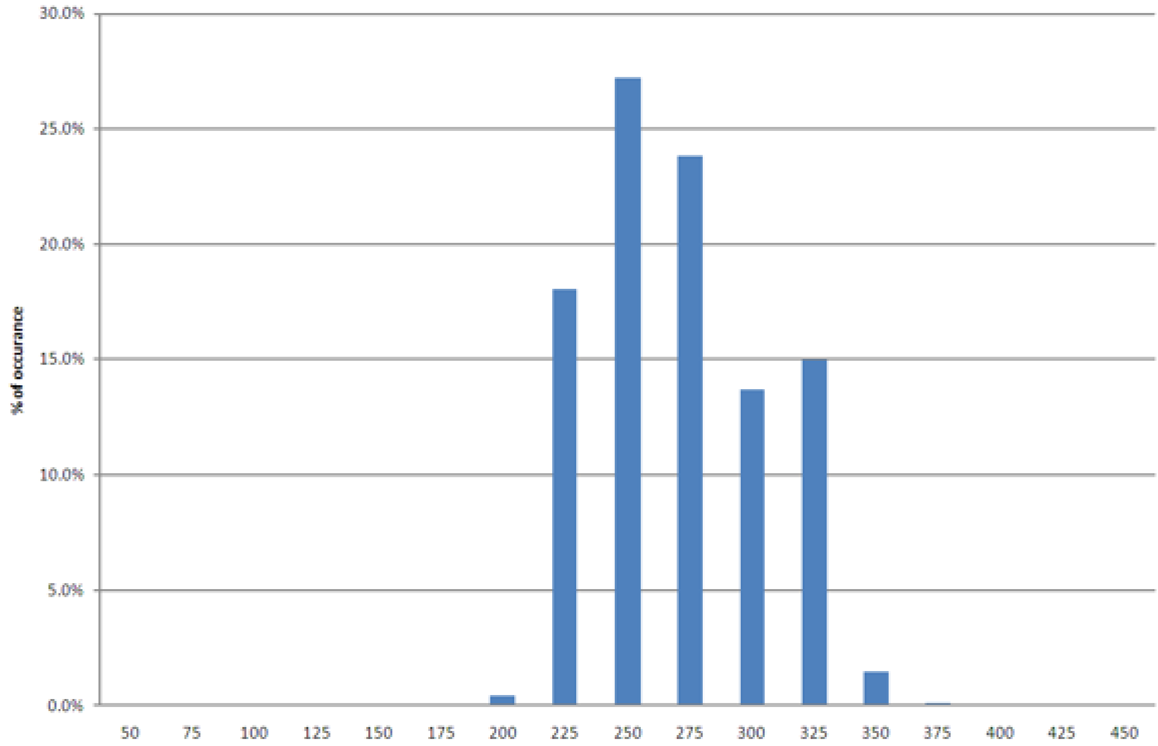

Figure 27: 500-ton Chiller Running at Different Cooling Capacities

By selecting suitable state-of-the-art chillers whose performance have markedly improved and sizing the chillers, pumps and cooling towers correctly, the energy consultant would be able to reduce the energy consumption of the central chilled water system significantly. The energy consultant could also modify the chilled water piping to reduce the hydraulic losses and further reduce the energy consumption. However, the modifications must be practical and not disrupt the occupants in the building. More savings can also be expected when variable speed drives are applied to the chillers, chilled water pumps, condenser water pumps and the fans in the cooling towers.

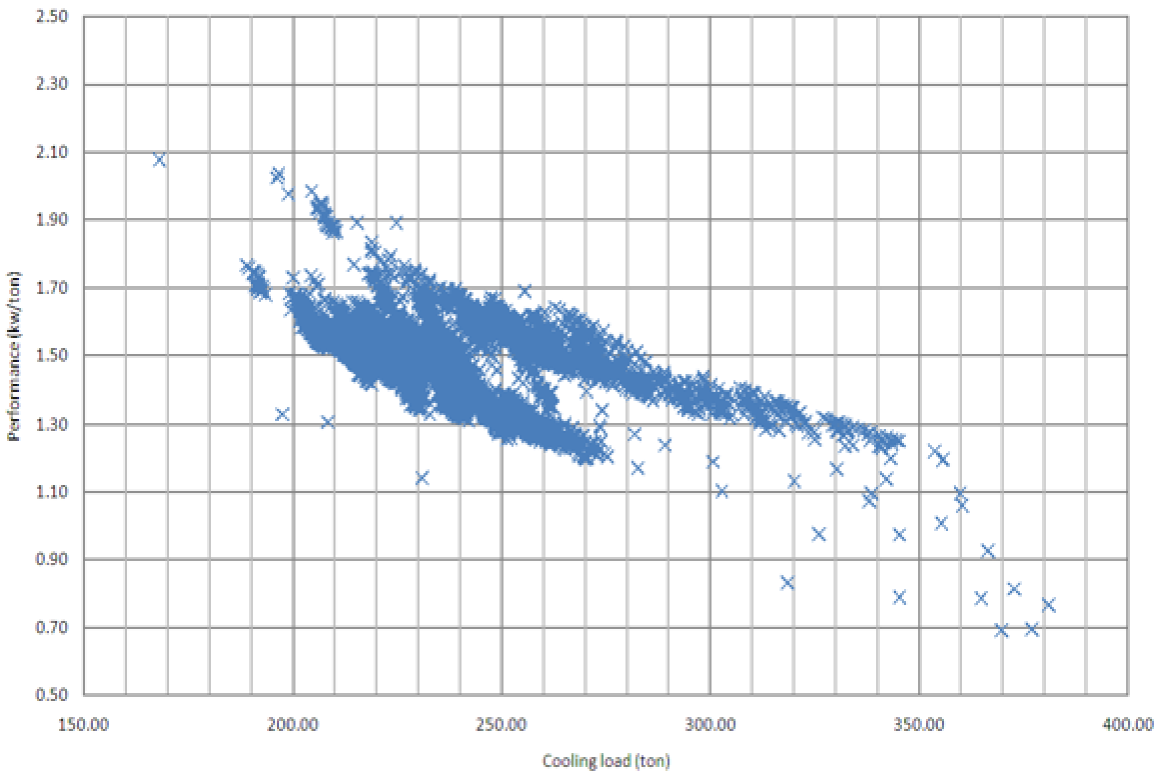

Figure 28: Plant Performance versus Cooling Load

The next consideration would be to assess the economic viability of replacing the central chilled water system. The new system is conservatively estimated to have a 10-year lifespan. The energy consultant estimated the following savings after the implementation of the chilled water system retrofit:-

Savings in energy	$ 403,200 per year
Savings in operations & maintenance	$ 100,000 per year
Total savings	$ 503,200 per year

The supply and installation of new chillers, pumps and cooling towers would require an investment of $1,832,000. The simple payback period is quickly computed to be 3.64 years

$$\text{Simple payback period} = \frac{\$1,832,000}{\$503,200}$$

$$= 3.64 \text{ years}$$

If the project is financed using bank loans charging 5% per annum, the net present value is computed to be $2,053,577.

Table 15: NPV Computation

Year	Future Value (FV) of Savings	Present Value (PV) of Savings
1	$503,200.00	$479,238.10
2	$503,200.00	$456,417.23
3	$503,200.00	$434,683.08
4	$503,200.00	$413,983.89
5[47]	$503,200.00	$394,270.37
6	$503,200.00	$375,495.59
7	$503,200.00	$357,614.85
8	$503,200.00	$340,585.57
9	$503,200.00	$324,367.21
10	$503,200.00	$308,921.15
total PV of savings at 5% p.a.		$3,885,577.02
less initial investment		$(1,832,000.00)
Net Present Value (NPV)		$2,053,577.02

As the projected savings is constant throughout the lifespan, the net present value might also be computed as follows:

PV = PMT x PVIFA(n=10, i=5%)
= $503,200 x 7.7217
= $3,885,559.44 (rounding error)

The energy consultant also determined that the internal rate of return (IRR) was 24.4%. However, when this economic analysis was presented to the building owner, scepticism over

[47] PV = FV x PVIF(n=5, i=5%)
= $503,200 x 0.7835
= $394,270.37

the consultant's projections of savings remained. The owner was also unwilling to make the investment of $1.8 million to fund the chiller replacement project.

The owner and the energy consultant negotiated and agreed on implementing the energy efficiency project through an energy performance contract. The energy consultant, taking the role of the EPC contractor, would invest in the new chilled water system and receive a substantial part of the savings for a period of six years. He therefore bore the risks of ensuring that the new chilled water system would performe as predicted. Should there be more savings than expected, he would be handsomely rewarded by receiving more than the profits expected from the contracting works as well as the fees for consultancy works. However, if the savings fell short of expectation, the owner need not pay the energy consultant beyond the six year period.

After implementation, the monthly energy consumption is compared to the baseline. The difference between the two numbers is the savings that had been achieved from the energy efficiency project. The baseline and actual energy consumption are shown graphically in Figure 29.

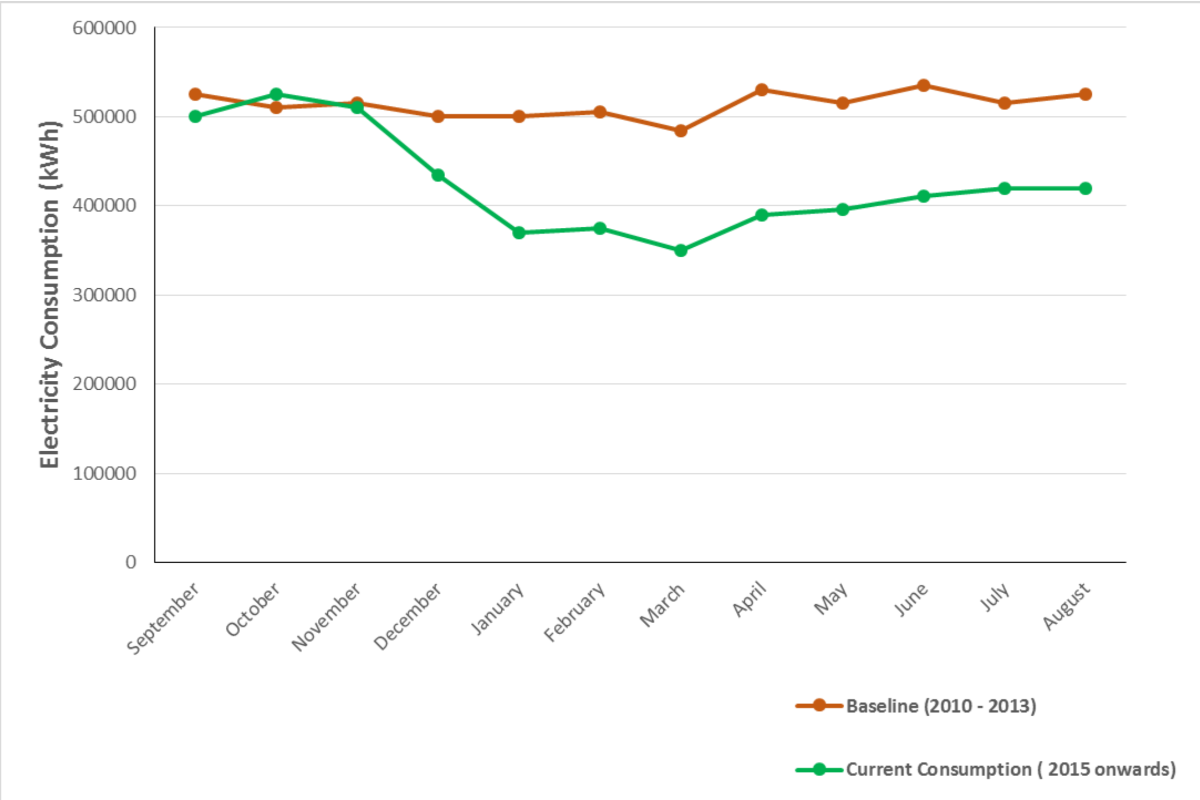

Figure 29: Monthly Energy Consumption compared to the baseline

Exercises (III)

Question 3.1

A company is considering a $100,000 investment in an energy efficiency project. It can be expected that there be 5 years of $25,000 savings per year. If the cost of capital is 8%, is this project viable?

Question 3.2

The factory manager is deciding if all the T8 lamps should be replaced with T5 lamps. The T8 lamps are rated 40W and have ballasts consuming a further 10W. The T5 lamp which gives the same lighting level uses 18W less and cost $32 each. The lamps are switched on for a total of 6800 hours a year and the T5 lamp can expect an economic lifespan of 3 years. The cost of electricity is $0.15 per kWh.
Do you support the replacement of the lamps if the company has a hurdle rate of a 20% internal rate of return?

Question 3.3

An electrical energy audit indicates that energy consumption of the electrical motor is 4,000,000 kWh per year. By upgrading the motor spares with high efficiency motors, a 10% saving can be realised. Assuming a $0.15 per kWh energy charge and a 20-year lifespan, is the expenditure of $150,000 to replace the motors justified based on a minimum rate of return of 15%?

Question 3.4

An economizer costs $20,000 and will last ten years. It will generate savings of $3,500 per year, with maintenance costs of $500 per year. If the minimum attractive rate of return is 10%, is the economizer an attractive investment? Use the net present value as the measure of worth.

Question 3.5

An efficient air compressor is proposed by a vendor. The compressor will cost $30,000 to install and will require $1,000 worth of maintenance each year for its life of 10 years. Energy costs will be $6,000 per year. A standard air compressor will cost $25,000 and will require $500 worth of maintenance each year. Its energy costs will be $10,000 per year. If the company's rate of return is 10%, would you recommend investing in the energy efficient air compressor?

Question 3.6

One disadvantage of using the Simple Payback Period (SPP) to assess an energy efficiency project is :

a) SPP takes into account the time value of money
b) SPP is easy to use
c) SPP is related to the computation of return-on-investment (ROI)
d) SPP does not account for cash flow after the payback period

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Solutions to Selected Exercises

Question 1.1

You have been appointed the energy manager of a manufacturing plant that employs some 300 people. You have been asked to brief the executive management on the energy management process. How might you describe this process in your presentation?

Solution 1.1

The key steps in the energy management process are:

i. Getting commitment

This includes setting up a committee with representatives from all departments in the organisation, communicating the objectives of energy management and assigning accountability.

ii. Assess the energy performance

Energy accounting centres are formed and the energy data is analysed. Energy saving targets are set .

iii. Create an action plan

Perform energy audits and identify opportunities to improve energy efficiency.

iv. Implement the action plan

Action plans implemented by the respective user departments must be co-ordinated to achieve overall coherence to corporate goals.

v. Control and monitor results

Performance of action plans must be assessed through control and monitoring

vi. Recognise efforts

This is a powerful motivational force to eventually integrate energy efficiency measures into standard working procedures.

vii. Re-assessment

This might include setting new goals

Question 1.2

You are an employee in an energy-intensive factory and this plant has a staff strength of 200 people. The various departments in the company are:

- Facility / Maintenance Department
- Production Department
- Finance Department
- Sales and Marketing Department
- Human Resource Department

You have been appointed the energy manager. Who should be represented in your energy management team? State their roles and responsibilities.

Every department will be represented in the energy management team. Since this is an energy intensive factory, perhaps two representatives from each department should be on this team. Also, there should be two representatives from the facilities management department. The remaining departments could assign one representative each to join the energy management team.

The representatives from the production department could provide expertise in the production process. They could identify the opportunities in saving energy with little or no impact to the production process and the quality of the product.

The role of the representatives from the facilities management department could be in conducting energy audits and addressing technical matters.

The representative from the sales and marketing department could assist in preparing materials to communicate the energy-saving efforts to both staff as well as to the wider community.

The representative from the finance department would naturally assume the role of ensuring there are sufficient funds for the energy efficiency projects. This might include having to borrow from banks or raising money from internal sources.

The representative from the human resource department can help identify training gaps so that the staff can be trained with relevant knowledge to support the implementation of energy efficiency projects. He / she could also advise on the appropriate recognition and/or reward for the staff involved in the energy projects.

Question 1.3

Calculate the fixed energy consumption for a rolling mill consuming 300,000 kWh of electricity to produce 500 metric tons (MT) of products per month and having specific energy consumption of 500 kWh per metric ton (MT).

Total energy consumed = Fixed Energy Consumption + (Specific Energy Consumption x Production)

Fixed energy consumption = Total energy consumed – (Specific energy consumption x Production)

Given,

Total Energy Consumption = 300,000 kWh per month

Specific Energy Consumption = 500 kWh per MT

Total Production = 500 MT

Fixed Energy Consumption = 300,000 – (500 x 500)

= 50,000 kWh of electricity per month

Note

In this exercise, a suitable performance indicator (EnPI) could be $\frac{300,000\ kWh}{500\ MT}$ *= 600 kWh/MT. If the production had been 800 MT, it can be estimated that the energy consumption would be 450,000 (or 500 x 800 + 50,000) kWh or an EnPI of 562.5 kWh/MT. This indicates how EnPI reduces as fixed energy costs are spread over a greater number of output units.*

Question 2.1

Your factory is using high tension electricity supply. You are currently buying electricity supply from SP Services. Your demand for electrical supply is quite constant throughout the 24-hour operations.

a) how do you know if your factory is a contestable consumer which means you can change the electricity retailer; who should you approach to find out?
b) how do you select a retailer ?
c) when reviewing the electricity retailer quotation, there are other costs such as a cost for *use of system* charges; what are the charges for ?

Solution

i. In the first instance, you as the energy manager, would have noticed that the factory's monthly consumption of electricity has exceeded the threshold for contestability. That means the factory has been consuming over 2,000 kWh per month.

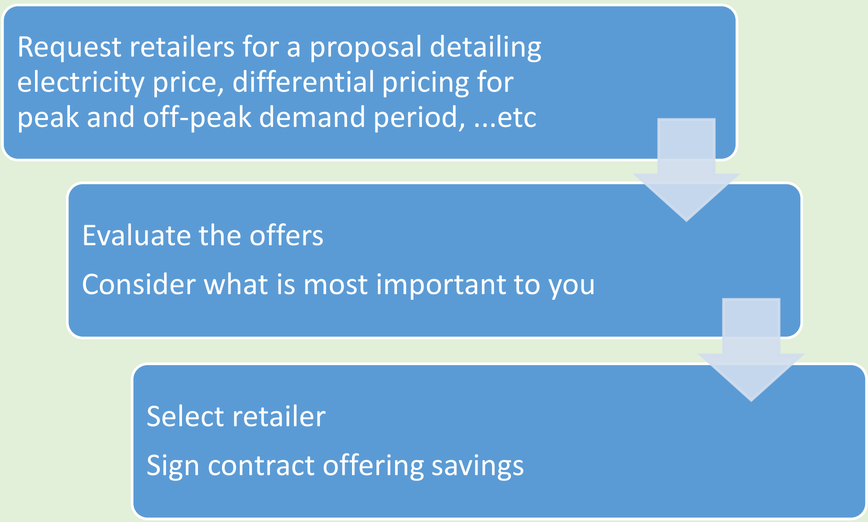
   If this level of consumption continues for a one-year period, SP Services will inform you that your factory qualifies for contestability. Once your factory is contestable, it has three options from whom you may buy electricity:

   i. continue buying from the MSSL, SP Services
   ii. buy from the wholesale market , or
   iii. buy from a retailer

You may also contact SP Services or any of the retailers to seek confirmation of your status. It is not compulsory for an eligible consumer to switch to become a contestable consumer.

ii. The retailers may need this information before they can give you an offer:
    i. the average monthly energy consumption
    ii. the consumption profile especially your peak demand periods and off peak demand periods
    iii. does your factory have more than one contestable account

Here's a 3-step guide to selecting a retailer:



Having invited perhaps three (3) or more retailers to submit offers, you will have to evaluate to see which of these offers best suit your factory's needs. Here are some questions that will help differentiate the proposals

i. what sort of discounts are offered?
ii. are there any other fees?
iii. what is the mode of payment?
iv. what billing options does the retailer offer?
v. is there a transfer fee for switching to this option?
vi. does the retailer pass through this cost or can they absorb?
vii. is there a security deposit?
viii. do I get any compensation if my retailer terminates my contract prematurely
ix. are there any termination charges if i decide to end my contract prematurely?
x. is my retailer allowed to make changes to the terms and price of the contract during contractual period?
xi. what sort of risk management tools does the retailer offer?

iii. The use of system (UOS) charges are costs related to the transmission of electricity through the power grid. There are also other third party costs which the energy manager should bear in mind:-

i. Monthly Energy Uplift Charge
Include:

a) Cost of procuring contracted ancillary services & related cost
b) Compensation claims & refunds
c) Financial penalties & refunds
d) Estimated monthly energy uplift shortfall to be recovered and/or deducted in following calendar month

ii. EMC Administrative Charge

Approved administrative costs for EMC to operate the NEMS

iii. PSO Administrative Charge

Approved administrative costs for PSO to operate the WEM

iv. Allocated Regulation Price (AFP)

Cost of purchasing regulation products from the market

Question 3.1

A company is considering a $100,000 investment in an energy efficiency project. It can be expected that there be 5 years of $25,000 savings per year. If the cost of capital is 8%, is this project viable?

Solution :

Cost of investment

= $100,000

Savings

= $25,000 per year

Present value of savings

= $\$25,000 \times PVIFA_{8\%\ 5yrs}$

= $25,000 x 3.9927

= $99,817.50

The net present value (NPV)

= $100,000 - $99,8817.50

= - $182.50

Since the NPV is negative, the project is not viable.

Question 3.2

The factory manager is deciding if all the T8 lamps should be replaced with T5 lamps. The T8 lamps are rated 40W and have ballasts consuming a further 10W. The T5 lamp which gives the same lighting level uses 18W less and cost $32 each. The lamps are switched on a total of 6800 hours a year and the T5 lamp can expect an economic lifespan of 3 years. The cost of electricity is $0.15 per kWh. Do you support the replacement of the lamps if the company has a hurdle rate of a 20% internal rate of return.

Solution :

Energy savings
= 18 W per lamp

Operating duration
= 6,800 hours per year

Energy savings
= 18 W x 6800 hr
= 122.4 kWh per year

Cost of electricity
= $0.15 per kWh

Annual savings
= 122.4 kWh x $0.15
= $18.36 per year

Investment cost
= $32

Present Value (PV) of inflow = PV of investment
Internal rate of return (IRR) = 33%

Since IRR exceeds the factory's hurdle rate of 20% (IRR), the investment should be supported

Question 3.3

An electrical energy audit indicates electrical motor consumption is 4,000,000 kWh per year. By upgrading the motor spares with high efficiency motors, a 10% savings can be realised. Assuming a $0.15 per kWh energy charge and a 20-year life, is the expenditure of $150,000 to replace the motors justified based on a minimum rate of return of 15%?

Solution

Using the life cycle cost analysis:-

	Alternative I : status quo	Alternative II : replace motor
Capital expenditure	$0.00	$150,000.00
Energy Costs	4,000,000 kWh per year x $0.15 per kWh = $ 600,000 per year	3,600,000 kWh per year x $0.15 per kWh = $540,000 per year
Present Value	PV= $600,000 x PVIFA(15%, 20yr) = $600,000 x 6.2593 = $3,755,598.88	PV= $540,000 x PVIFA(15%, 20yr) PV= $540,000 x 6.2593 = $3,380,039.00
Life Cycle Costs	$ 0.00 $3,755,598.88 $3,755,598.88	$ 150,000.00 $3,380,039.00 $3,530,039.00

The $150,000 investment is justified since the LCC of Alternative II is lower