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An Introduction for Policy Makers

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- An Introduction for Policy Makers

SUSTAINABLE ENERGY FOR ALL

Best Practices and Case Studies for Industrial Energy Efficiency Improvement

- An Introduction for Policy Makers

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Preface

Two major international agreements reached in 2015 will be guiding the future energy development patterns in all sectors, including industry. At the United Nations General Assembly in September 2015, global leaders adopted 17 Sustainable Development Goals to mobilise efforts to end all forms of poverty, fight inequalities and tackle climate change by 2030. Goal 7 is specifically about providing clean and affordable energy to all and energy services will be important for the achievement of all goals. In December 2015, the 21st session of the Conference of the Parties (COP21) to the UN Framework Convention on Climate Change established the Paris Agreement to address the urgent challenge of global climate change. A total of 160 Intended Nationally Determined Contributions (INDC), reflecting 187 countries (EU submitted one INDC for its 28 member states) provides the foundation for the Paris Agreement presenting concrete plans and targets for climate change mitigation and adaption actions by 2030. Energy efficiency is one of the key mitigation options included in plans of many countries.

Globally the industrial sector is responsible for around one-quarter of total energy consumption, and in many countries it is concentrated in a small number of industrial facilities, making it relatively easy to identify the big energy consuming enterprises. Therefore, improving energy efficiency in the industrial sector is being prioritised in many countries. Investment to improve industrial energy efficiency can deliver large energy savings, improved productivity, and reduced environmental pollution. However, in many cases information, financial, and regulatory barriers are continuing to prevent enterprises from fully realising the potential opportunities offered by improving energy efficiency. A wide range of policies and programmes can be adopted to help overcome these barriers.

Sharing best practices, particularly various approaches towards policy making and success stories can help countries accelerate energy efficiency improvement, and countries are interested to learn from international experiences in these areas. This book is aimed at supporting countries in industrial energy efficiency policy making through sharing international experiences. It explains preconditions for successful implementation of policies and programmes while providing concrete examples. The overall objective is to stimulate joint actions from business, governments, and civil societies to help realise the SE4All goal of doubling the global energy efficiency improvement rate by 2030.

The authors of this book, Steven Fawkes, Kit Oung, and David Thorpe have extensive experiences in supporting the implementation of industrial energy efficiency projects. The book has been reviewed by Xianli Zhu and Timothy C Farrell from the Copenhagen Centre and Stephane de la Rue du Can from Laurence Berkley National Laboratory. Timothy C Farrell also helped with editing the book. Xianli Zhu coordinated the preparation of this book and was supported by suggestions from others at the Copenhagen Centre.

The Centre plans to bring out as well as make available energy efficiency best practices publications of various partners to stakeholders, and this publication exploring international best practices for energy efficiency improvement in the industrial sector is a part of the plan.

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Introduction

Interest in improving energy efficiency is increasing at corporate, local, national and international levels around the world. It is seen as a means of addressing concerns about environmental impact resulting from the use of energy and concerns about energy security. In the words of the G8 Clean Energy and Development Report; "*Improving end-use efficiency offers the greatest opportunity to address energy security, price and environmental concerns*". Energy efficiency is also increasingly being recognised as being profitable without subsidies and capable of delivering multiple other non-energy benefits. Amongst these are better productivity, job creation, reduced fuel poverty and improved public health. These benefits have recently been recognised due to pioneering work by the International Energy Agency (IEA 2014a).

This book focuses on energy efficiency in the industrial sector. The techniques and technologies to improve industrial energy efficiency have been well proven. The challenge for policy makers is to accelerate the adoption of those techniques and technologies. This book is intended to support their work.

Globally, industry accounts for about 29% of final energy consumption and about 23% of the world's workforce. Improvement in energy efficiency is needed in all sectors but targeting industrial energy consumption offers major advantages for policy makers because it is more concentrated in terms of entity numbers and often a small number of big energy-intensive enterprises consume the majority of energy in the sector. The Pareto Principle, or 80/20 rule, generally applies to this sector, in that about 20% of industrial sites often consume 80% of the energy used by all of industry. Nearly two thirds of all industrial energy consumption is accounted for by just four sectors: chemical & petrochemical (33%), iron and steel (17%), cement (9%), and pulp and paper (5%) (IEA 2008). Achieving improved energy efficiency in industry can make a significant contribution to solving local, national and global energy problems.

This book reviews policies, programmes and experiences in industrial energy efficiency to inform and guide policy makers. Although the book focuses on energy intensive industries, many of the approaches described can also be applied to other industrial and commercial sectors as well as small and medium enterprises (SMEs). Evidence from Europe (Ecofys 2007) has revealed a lack of data on the performance, costs and benefits of energy efficiency policies, with a greater effort required on measuring, verification and reporting. International experience shows that successful policies and programmes depend on effective design, implementation and ongoing evaluation.

Chapter 1 starts with a description of the current global energy situation, particularly in regard to industry, and future scenarios up until 2040. It then examines the reasons why addressing energy efficiency in industry should be a priority, particularly in developing countries where industry often accounts for a large proportion of energy use.

Chapter 2 makes the case for a strong energy efficiency policy. It starts with recognising the reasons why energy efficiency policy creates problems for policy makers compared to energy supply options. It then looks at the economic, energy security and environmental arguments for energy efficiency and the other multiple benefits that accrue.

Chapter 3 defines what we mean by energy efficiency and other related terms. It then goes on to look at the potential for energy efficiency in industry and asks the question: "is there a limit to energy efficiency?" The rebound effect – the idea that improving energy efficiency leads to increased energy consumption – is also examined.

Chapter 4 describes energy management systems and the common technologies used to improve energy efficiency, both cross-sectoral and sector specific. The key message is that the processes of energy management and energy efficiency technologies across all sectors are well proven and mature. The challenge for policy makers is how to accelerate the uptake of these cost-effective technologies and practices.

Chapter 5 examines the barriers to improving energy efficiency, both at government/policy making level and within enterprises. Policy makers need to understand the barriers at these levels in order to design effective policies. In particular, it is essential that policy makers understand the decision-making process within enterprises, which are further explored. As Stefan Scheuer, Secretary General of the Coalition for Energy Savings, has said: "*Removing barriers to energy efficiency is a lot smarter and cheaper than trying to get millions of individuals over these barriers*".

Chapter 6 sets out the basic policy levers that are available to policy makers. It begins with some general principles of policy design and considers the importance of creating industry specific policies. It moves on to look at the importance of measuring success, possible indicators, and concludes by presenting possible sources of assistance.

Chapters 7 to 10 explore the four different types of policy and programmes: information-led and capacity building policies; institutional, regulatory and legal policies; fiscal and financial policies; and technology development policies. Respective chapters consider the main issues, best practices and case studies for each type.

Chapter 11 summarises the overall conclusions of the book.

CHAPTER 1.

Energy and Industry

"A modern industrial society can be viewed as a complex machine for degrading high-quality energy into waste heat while extracting the energy needed for creating an enormous catalogue of goods and services."

– Claude Summers, 1971

1.1 Introduction

This chapter looks at global energy usage now and in the future, as well as considering the contribution of the industrial sector.

Access to energy is the life-blood of all economies. As economies industrialise, grow and become dependent on more sophisticated infrastructure and technological systems, energy becomes ever more important to individuals, enterprises and nations. Yet the world faces a number of energy-related problems and constraints that potentially threaten continued industrialisation and economic growth. These include: the threat of resource depletion, international action to address the threat of catastrophic climate change, rapidly growing energy demand in oil-producing countries that could reduce exports, threats to energy production from global terrorism, growth in electricity demand above the expansion of supply infrastructure, worsening indoor and outdoor air quality, and ageing energy infrastructure in industrialised countries.

1.2 Global energy use

Global primary energy use in 1973 was 4,672 million tonnes of oil equivalent (mtoe). By 2012 this had increased to 13,361 mtoe. The same data set from the International Energy Agency (IEA) shows that, while Europe's total final energy consumption has declined in recent years, in all other regions it has increased – with the most significant growth being in Asia and the non-OECD Americas.

Energy productivity is the ratio of economic output (i.e. GDP) to energy input (measured in thousand USD per toe). The higher the ratio, the more efficiently energy is being used. Worldwide, between 2001 and 2011, it increased by an average of 1.3% per annum. Improving the rate of increase in energy productivity is necessary to achieve a low carbon future and addressing environmental constraints.

1.3 Looking forward to 2040

The International Energy Agency's 2014 World Energy Outlook (WEO) (IEA 2014d) presents three scenarios for energy use up to 2040: New Policies, Current Policies and 450 Scenario. These are explained as follows:

> **New Policies** – "the New Policies scenario takes into account existing policies and implementing measures affecting energy markets that had been adopted as of mid-2014, together with relevant policy proposals, even though specific measures needed to put them into effect have yet to be fully developed. These proposals include targets and programmes to support renewable energy, energy efficiency, and alternative fuels and vehicles as well as commitments to reduce carbon emissions, reform energy subsidies and expand or phase out nuclear power."

> **Current Policies** – "takes into consideration only those policies and implementing measures that had been formally adopted as of mid-2014. In other words, it describes a business-as-usual future in which governments fail to follow through on policy proposals that have yet to be backed up by legislation or other bases for implementation and do not introduce any other policies that affect the energy sector."

> **450 Scenario** – "takes a different approach, adopting a specified outcome – the international goal to limit the rise in long-term average global temperature to an absolute maximum of two degrees Celsius (2°C) – and illustrating how that might be achieved. The scenario assumes a set of policies that bring about a trajectory of greenhouse-gas emissions from the energy sector that is consistent with the goal."

The New Policies scenario is effectively the base case for the IEA, in which energy demand grows by 37% to 2040 at an average annual growth rate of 1.1%, with energy demand shifting away from OECD countries. WEO 2014 estimates primary energy demand for 2020 and 2040 for the three scenarios (Table 1). The table shows that under all scenarios fossil fuels are likely to supply a significant proportion of total energy demand through 2040 and beyond. Furthermore, non-OECD countries will account for a growing share of global energy demand as they industrialise and their populations increase. Achieving

Table 1. World primary energy demand to 2040 by scenario (mtoe)

		New Policies		Current Policies		450 Scenario	
	2013	2020	2040	2020	2040	2020	2040
Total	13,559	14,743	17,934	15,041	19,643	14,308	15,197
Fossil fuel share	82%	79%	75%	80%	79%	78%	60%
Non-OECD share	60%	63%	70%	63%	69%	63%	69%

Figure 1. Final energy consumption by sector 2012
Source: IEA. 2014d

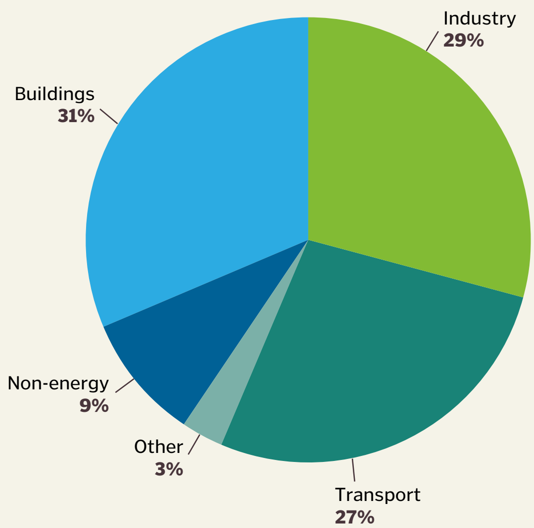
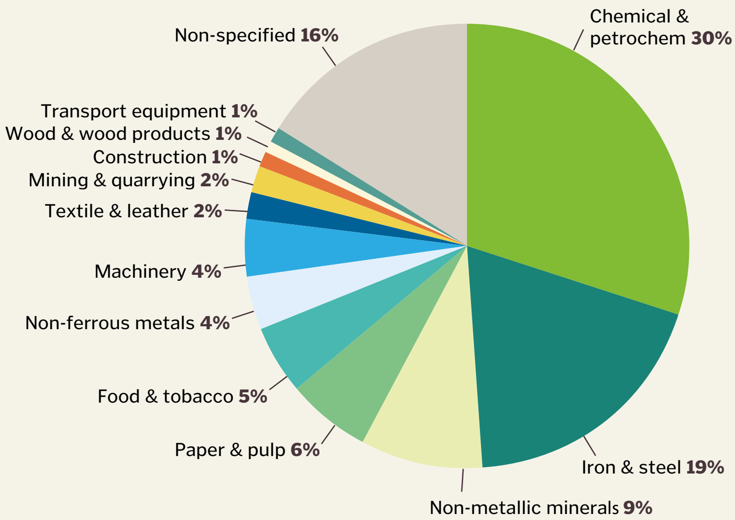


Figure 2. Breakdown of industrial energy use by sector 2004
Source: IEA, 2007



higher levels of energy productivity through efficiency gains is therefore essential in the New Policies and the 450 scenarios.

1.4 Industrial energy usage

Since the industrial revolution, manufacturing – and in particular continued improvements in industrial productivity – has driven economic output and employment around the world. Productivity improvements have led to falls in the prices of manufactured goods which has increased demand. Industry as a whole remains an important employer with around 724 million jobs worldwide in 2013 – or around 23% of the world's 3.1 billion workforce. Industry accounted for 26% of global gross domestic product (GDP) in 2014 (World Bank 2014).

Economic development tends to follow a similar pattern everywhere. At very low incomes agriculture often accounts for a relatively high share of GDP. As economies grow, manufacturing's share of GDP grows and reaches a peak of about 20% of GDP at roughly USD 14,000 of GDP per capita (UNIDO 2013). As incomes rise above that level the share of services in total GDP continues to rise and agriculture's share continues to decline.

The current global breakdown of total energy consumption between sectors shows that industry accounts for 29% of final energy consumption (Figure 1).

The breakdown of energy use by the industrial sector shown in Figure 2 illustrates the heavy proportion of energy use accounted by the four sectors, chemicals and petrochemicals, iron and steel, non-metallic minerals and pulp and paper. These account for nearly two thirds of all industrial energy consumption. This type of distribution is mirrored in many countries.

As it consumes a large proportion of total energy, improving the energy efficiency of industry should be prioritised. As shown in Figure 2 a large proportion of energy use is consumed within a few industrial sub-sectors, and large industrial energy users are often concentrated around specific sites. These factors help to make improvements to energy efficiency in industry easier compared to other sectors where energy use is often dispersed amongst many more sites and users.

1.5 Energy intensity is falling but needs to be accelerated

Energy intensity is defined as the amount of energy needed to produce a unit of GDP, usually expressed as tonnes of oil equivalent (toe) per USD 1,000 of GDP in constant terms. It has been falling steadily over the last decade at an average of 1.5% per annum. Data from the IEA suggests energy intensity fell 2.7% in 2014. Over the last four years the drop has been higher than the trend over the last two decades. Energy intensity is affected by factors other than energy efficiency, such as changes to the structure of a country's economy and fuel switching. Analysis shows that without energy efficiency global energy consumption in 2014 would have increased 2.1% rather than the actual rate of 0.7%. This suggests energy efficiency saved 122 mtoe (IEA 2015b). The IEA also estimates that investments in energy efficiency since 1990 saved a cumulative 520 mtoe. This figure is larger than the total annual energy consumption of Japan and Korea combined (IEA 2015a).

Energy efficiency has a vital part to play in all future energy scenarios. In the IEA's New Policies scenario improved energy efficiency limits energy demand growth to one-third by 2040 even though the global economy grows by 150%. To restrict the average global temperature rise to even 2°C, let alone the 1.5°C aspiration specified by the Paris Agreement on climate change adopted at COP21, the world has to accelerate the long-term reduction in energy intensity through more aggressive energy efficiency policies. The size of industrial energy use makes improving industrial energy efficiency a key task for the coming years. As we will see in the next chapter, this will bring many benefits at several levels.

Key points:

- Industry consumes 29% of global energy.
- Global energy use is likely to rise one-third by 2040 while the economy grows 150%.
- Nearly two-thirds of industrial energy use is accounted for by four industries: chemical and petrochemical, iron and steel, non-metallic minerals and paper and pulp.
- High energy intensity on a limited number of sites makes industrial energy efficiency a high priority.
- We need to accelerate improvements in energy efficiency to achieve a 2°C or less global temperature rise.

CHAPTER 2.

The Case for a Strong Energy Efficiency Policy for Industry

"Doubling energy productivity would reduce the global fossil fuel bill by more than €2 trillion and could create more than six million jobs globally by 2020."

– The 2015 Energy Productivity and Economic Prosperity Index

2.1 Introduction

This chapter makes the case for a strong industrial energy efficiency policy. The arguments are based on three factors: economic, energy security and environmental. The energy benefits and the non-energy benefits of improving industrial energy efficiency are examined.

Energy policy has traditionally been almost entirely concerned with energy supply and most often focused on the electricity system. The close link between electrification and modernisation has given the electricity supply industry in all countries a strong political voice. Energy efficiency, energy conservation or "energy savings" has tended only to be given a high priority in times of crisis, when energy prices are particularly high or when economies face electricity shortages. This was most notable during the "oil crises" of the 1970s. Until recently, energy efficiency policy has always had a lower priority in energy policy development compared to energy supply.

But mounting evidence on both the economic potential for improving efficiency and the large energy and multiple non-energy benefits that accrue from improving efficiency has pushed energy efficiency up in the political agenda in many countries in the last few years. There are many non-energy benefits including: enhanced economic development, improved energy security, job creation, better air quality and health, and reduced emissions. The European Union has recognised the importance of energy efficiency and in its final Energy Union document said that "*Member States [should] give energy efficiency primary consideration in their policies*" (European Commission 2015). The IEA has called efficiency "*the first fuel*" (IEA 2014b). These developments reflect increased focus and effort to make energy efficiency mainstream and a valuable resource within the energy system.

The multiple benefits to adopting strong policies on energy efficiency are described below, but first we should acknowledge that energy efficiency does present some real difficulties for policy makers.

2.2 The difficulties that energy efficiency policy presents

Before looking at the elements of successful energy efficiency policies, it has to be recognised that crafting an effective energy efficiency policy presents a number of challenges for policy makers. This section helps to explain why energy efficiency has typically not received a high priority in government circles, despite its cost-effectiveness and multiple non-energy benefits. These challenges include:

- Fundamentally there is no actual market for energy efficiency but rather a number of markets for various equipment and services that result in improved energy efficiency.
- A lack of understanding and appreciation of the value of the benefits of energy efficiency – both energy benefits and non-energy benefits (a lack of capacity).
- A lack of understanding and appreciation that for improved energy efficiency to happen there needs to be simultaneous action on three fronts – end users/customers, the energy efficiency supply chain, and financiers.
- A lack of relevant data and difficulties with measurement.
- Energy efficiency often cuts across government organizational boundaries, for instance when different Ministries have responsibility over different sectors, e.g. buildings, industry, transport and energy.
- Energy efficiency is largely invisible and so does not reinforce the idea that the government is "doing something".
- Energy efficiency often involves many relatively small decisions and investments across an economy rather than the few large decisions and investments required by the energy supply side.
- The energy supply industry is dominant because of its importance in traditional models of economic development and the scale of investment involved. At best the energy supply industry does not fully understand or appreciate efficiency and at worst it can actively oppose greater deployment of efficiency as it is seen to reduce its revenue stream.

2.3 The case for a strong energy efficiency policy

The arguments for having a strong and effective industrial energy efficiency policy are in three categories: economic, enhanced energy security and reduction in environmental impact. The evidence for the benefits in all three categories is growing. **As well as helping to create employment and growth, improving energy efficiency is a cheaper option than energy supply alternatives, whether conventional or renewable**. It can also be brought "on-line" much quicker than any energy supply option. Energy efficiency should be thought of as another energy resource.

2.3.1 Economic arguments

Economic arguments for energy efficiency often focus on job creation, enhanced competitiveness and economic development. Each of these may have a different relative appeal to policy makers in specific countries.

Various estimates of job creation from energy efficiency programmes are available from several sources. In one study, the American Council for an Energy Efficient Economy (ACEEE 2011a) notes that a cost-effective energy efficiency investment can create jobs by redirecting funds away from less labour-intensive sectors of the economy to more labour-intensive activities. An investment in energy efficiency will first create opportunities for workers in industries that are more labour-intensive than average. Then it will continue to support jobs every following year by saving energy. This redirects spending away from the energy industry, which, in the United States, supports just under 10 jobs per USD 1 million spent. This spending goes back into the overall economy, which supports 17 jobs per USD 1 million spent.

Three types of jobs are created by investment in energy efficiency:

- workers installing the desired measures (direct employment)
- workers producing the materials and tools to be used (indirect employment)
- workers producing services and goods bought with the money saved from not spending it on energy.

Using the ACEEE figures, an investment of USD 15 million which saves USD 3 million a year for 20 years would achieve a net gain of 21 jobs per year.

The nature of the impacts of energy efficiency measures on the economy changes over time. In the short term it is dominated by increased activity in the construction and manufacturing sectors that supply energy efficiency measures. In the long term sectors that focus on consumers will benefit, either in the service industries, or in producing goods that can be bought by the increase in disposable income.

Energy efficiency can also contribute to industries and enterprises becoming more competitive in local and global markets by reducing their cost base. In some sectors and markets, demonstrating high levels of energy efficiency and wider sustainability may also be an advantage for suppliers operating in a competitive global marketplace, as consumers' purchasing decisions are increasingly influenced by environmental concerns.

As well as job creation and greater competitiveness, improved energy efficiency can contribute to economic growth by reducing the need to spend foreign currency on importing energy. It can delay the financial investment needed to increase energy supply capacity and allow this investment to be transferred to other areas of need, thus contributing to economic development. The IEA estimates that large-scale energy efficiency has a positive impact on GDP of between 0.25% and 1.1% per annum and creates between 8 – 27 job-years for every EUR 1 million investment (IEA 2014a).

Economists have traditionally examined the role of capital and labour in the growth of economies but rarely the importance of energy, and in particular the role of energy efficiency, or its inverse, energy productivity, as a driver of growth. Although there is as yet no consensus that improving energy efficiency can drive economic growth this view has been supported by a number of studies (see for example ACEEE 2011 and The Climate Institute 2012).

2.3.2 Improved energy security

Energy security has several dimensions: access, affordability, adequacy, and availability (which can be time and season dependent). It is about the risks of supply disruption and is most often thought about in terms of the reliability of fossil fuel imports. Improving energy efficiency in major fuel-using processes in the most fuel-intensive sectors (e.g. iron and steel, chemicals, glass etc.) can directly reduce the need to import fuel.

Reducing electricity consumption at the plant level can also have a significant knock-on effect on fuel usage at the level of generating stations – and therefore the need to import fuel. Although the world average efficiency for fossil fuel plants is 40%, many stations operate below this level. Even at 40% efficiency one unit of electricity saved at the power station level will save 2.5 units of fuel input to the power station. When the entire system efficiency from power station to actual end use – such as pumping – is considered, the multiplier factor is much larger. A typical industrial pumping operation with a motor, drive train, pump and throttling valve only produces 9.5 units of useful output for each 100 units of energy input into the power station (Lovins 2011). Therefore **electricity saved at the end use will reduce fuel input into the power station by a factor of 10**.

As well as the insecurity of fuel import dependence, other dimensions of security include the physical ability of energy supply systems (whether they be electricity or fossil fuels) to cope with demand, particularly at peak times. Improving industrial energy efficiency can reduce stress on electricity systems, particularly at times of rapid growth in demand, and delay the need for investment into new generating capacity. Although this is usually discussed in terms of electricity it also applies to other energy sources.

Although power supply capacity constraints are more often associated with rapidly developing countries, the developed world can also be affected in this way. For example, in the United Kingdom, due to enforced shut-down of large coal plants as a result of EU environmental legislation on SOx emissions, closure of ageing nuclear power stations, and failure to invest in new generating capacity, the supply capacity margin – the difference between peak generating capacity and peak demand has declined dramatically over the last ten years. The latest estimate is that it would fall to 1.2% over the winter of 2015/16 and 2016/17 (prior to special measures to manage demand and install standby generators being taken). In South Africa the electricity supply margin fell from 30% in 1993 to 10% in 2003 and since then it has fallen to close to 0%, leading to rolling blackouts. The economic and social effects of supply disruptions are huge. Reducing demand through improved energy efficiency and the introduction of demand response programmes, which encourage short-term switching of load to alleviate stress on the electricity system, can help alleviate supply capacity constraints.

2.3.3 Reduction in environmental impact

The environmental benefits of improving energy efficiency can be delivered at the global and local levels. For example, local benefits may include improvements in air quality, with positive economic effects such as reduced health care costs and fewer lost working hours due to illness. Arguments for improved energy efficiency based on addressing climate change can either be in response to international agreements, nationally imposed targets, public pressure, or a desire to take a leadership position. These factors can incentivise the acceleration of energy efficiency action such as the replacement of inefficient plant and infrastructure.

2.4 The multiple non-energy benefits of improving energy efficiency

Traditionally, the value of energy efficiency has been mainly associated with direct energy benefits, reduced energy costs and reduced exposure to energy price volatility. The full range and value of non-energy benefits has been highlighted by the International Energy Agency (IEA 2014a). When properly valued they can dramatically increase the financial attractiveness of energy efficiency investments and help build the business case. Non-energy benefits include job creation, increased productivity, and increased health and well-being. Recognition of these non-energy benefits is relatively recent and work is now underway to value them, at the corporate, national and international levels. In the UK for example the retailer Marks & Spencer, in partnership with the World Green Building Council, is undertaking work to place a value on benefits such as increased employee and customer satisfaction with an energy-efficient built environment. In the industrial sector two examples of non-energy benefits are shown in the text box[1] below.

Example of non-energy benefits in industry

Worsley Alumina, an Australian aluminium producer, initiated a system optimisation project with the stated aim of reducing energy demand. Ultimately, the measure delivered additional benefits in the form of reduced need for operator intervention (reduction of workload and operator error), improved system stability and reliability, lower maintenance needs and fewer charge-outs. These multiple benefits enabled the company to increase production by 3,000 tonnes of aluminium per year, translating into a commercial value of USD 6 million per year (USD/year). (DRET 2013)

A Danish company initiated an energy efficiency project to reduce energy demand in the process of producing liquid gases. Using a combination of an ozone unit and a sand filter, it was possible to reduce the temperature of cooling water. The project delivered energy savings of 153,000 kilowatt hours per year (kWh/year) corresponding to annual savings of USD 12 000. This process improvement also reduced the amount of required process chemicals (saving USD 50 000 per year), reduced the need for corrosion inhibitors (saving USD 12 000 per year) and reduced

[1] *Both of these examples are taken from IEA 2014a*

corrosion damage (saving USD 20 000 per year). In addition, the company noted reduced labour costs, less down time, reduced negative environmental impacts and an improved working environment. (Gudbjerg 2104)

The multiple benefits of improved energy efficiency arise at several levels within an economy, including the energy user, energy supply system and to the national economy. The direct national benefits are of most interest to policy makers, although the benefits to the energy supply system are also likely to be of great interest, particularly in economies where the energy supply industry is state owned or supported in some way. Even when this is not the case the energy supply industries are usually a significant player in most economies and therefore the benefits should be of interest to policy makers. The benefits at the end-user level can also have significant national implications e.g. a more competitive industrial base. Understanding the benefits at the end-user level, which drive investment decisions, is important for designing effective policies.

2.4.1 Benefits to the energy user

The direct, and most often considered benefit, of energy efficiency is a reduction in energy consumption for the same level of production and hence energy cost per unit of consumption. This is usually expressed as the "energy reduction" or "energy savings" of an energy efficiency project or a portfolio of energy efficiency projects, on the assumption that the level of production remains unchanged. Industrial energy users implementing improved energy efficiency also benefit from reduced exposure to energy price volatility, which in itself has an economic benefit. Additional non-energy benefits at the energy user level can include, amongst others: improved productivity, removing production constraints, and an improved working environment.

2.4.2 Benefits to the energy supply system

Improving end-use energy efficiency can bring direct and valuable benefits within the energy supply system. This is particularly relevant to the electricity supply system. Reducing power demand, particularly at times of peak demand – which can be encouraged through demand response programmes – can increase system reliability and ultimately reduce the need to install larger transformers, supply cables and ultimately power stations. In addition, energy efficiency within the system can also reduce the need for hot standby power plants that are consuming fuel without being connected to the system. Energy efficiency has the potential to become a resource within the electricity system that can be utilised in the same way that power stations are.

2.4.3 National benefits of improved industrial energy efficiency

The national benefits of improved industrial energy efficiency include:

- economic development
- reduced need to import energy/improved energy security
- climate change mitigation
- reduction of local pollution which can have a direct impact on health costs, for example by reducing respiratory disease
- increasing energy access: in a supply constrained economy, the reduction of energy consumption by one user frees capacity for others.

2.5 Conclusions

There are many compelling direct and indirect benefits of improving energy efficiency generally and specifically within the industrial sector. The benefits, particularly when placed in the context of the global energy scene, and national industrial policies, are many and significant in value. Energy efficiency is gaining a higher status within energy and industrial policies than ever before, but as we will see in the next chapter there is still a long way to go in order to realise the untapped potential benefits.

Key points:

- Improving industrial energy efficiency delivers multiple energy and non-energy benefits to the energy user, the energy supply system and the economy.
- The non-energy benefits should be recognised and properly valued.
- The economic arguments for a strong energy efficiency policy include, inter alia: job creation, improved productivity, competitiveness and economic development.
- Improved energy efficiency can improve energy security at local and national levels through reducing energy imports and the burden on electricity generation and distribution systems.
- Energy efficiency can contribute to improved local environmental conditions such as air quality.
- Energy efficiency is a major way of reducing emissions of greenhouse gases and therefore contributing to the achievement of a low carbon future.
- Energy efficiency should be considered as an energy resource in the same way that supply side resources are.

Photo: Hourann Bosci

CHAPTER 3.

Energy Efficiency – What Does it Mean and What is the Potential in Industry?

"Improving end-use efficiency offers the greatest opportunity to address energy security, price and environmental concerns".

– G8 Clean Energy and Development Report: Towards an Investment Framework

3.1 Introduction

One of the issues that may impede improvement in energy efficiency, both among policy makers and corporate decision-makers, is a lack of understanding of terminology. It is important that policy makers understand the meaning of key terms and this chapter starts by defining terms. It then looks at the potential for improved efficiency in industry and considers the question of whether there is a limit to improving efficiency. Finally it considers the rebound question, usually termed the Jevons paradox.

Energy is defined scientifically as the capacity of a system to perform work. In the context of industrial energy efficiency, energy refers to the various forms of energy source that can be purchased, stored, treated and used in equipment or in a process, such as oil, coal, gas and electricity. Energy uses include heating, cooling, production processes, transport and so on.

3.2 What do we really mean by energy efficiency?

Energy efficiency is a widely used term that suffers from issues of definition. This can be a cause of confusion. In a strictly technical definition, energy efficiency is simply useful energy output over energy input for any energy conversion device. For instance in an internal combustion engine, the energy output will be the rotational energy at the driveshaft whilst the energy input will be the chemical energy contained within the fuel. For a power station, the efficiency will be useful electricity out divided by the energy content of the fuel input.

However, this technical definition is not what is usually meant by energy efficiency. Energy is used in two types of systems: conversion devices such as internal combustion engines, light bulbs or power stations, and passive systems such as buildings where useful energy is degraded to low-grade heat in return for providing useful services such as thermal comfort (Cullen 2009). We commonly use the term "energy efficiency" to cover both of these situations. In the case of passive systems it is technically incorrect as there is no (useful) energy output from a passive system such as a building, only useful services such as comfort. Here, a more accurate term than energy efficiency is energy performance.

So the all-encompassing term 'energy efficiency' really incorporates two concepts: technical energy efficiency (useful energy out/energy in) for conversion devices, and energy performance (energy in/useful output) for passive devices and systems.

Typical measures of energy performance include litres of fuel per 100 kilometres for vehicles, kWh per square metre for buildings to produce a certain temperature for a certain period of time, or kWh per 1,000 units of production in a factory.

For practical purposes energy efficiency can be defined as follows:

> "Energy efficiency is measured as the ratio between the useful output of the end-use service and the associated energy input. In other words, it is the relationship between how much energy is needed to power a technology (for example, a light bulb, boiler, or motor) and the end-use service (for example, lighting, space heating, or motor power) that the technology provides[2]".

Improving energy efficiency or reducing energy input for a given output is a process of technical and/or behavioural change that is driven by technological, financial, management, social and policy drivers and constraints. When we talk about energy efficiency in a macro policy sense we usually mean a process of improvement rather than status at a single point of time. The fundamental energy efficiencies of all technologies tend to improve over time due to improvements to existing technologies and the invention of new technologies. Energy efficiency policy should be aimed at increasing this rate of improvement. In the industrial context this means accelerating the rate of reduction in energy use per unit of industrial output.

3.2.1 Energy intensity and energy productivity

Energy intensity refers to the overall energy efficiency of an economy measured as energy usage per unit of GDP. It is typically measured in toe per USD 1,000 of GDP (in constant Purchasing Power Parity terms). The inverse of energy intensity is energy productivity. There is an increasing use of this term as a rallying point and focus for energy efficiency efforts.

Energy productivity (measured in USD 1,000 of GDP per toe) is perhaps a more positive target as it emphasises improving productivity which is a positive feature. It moves away from some of the negative connotations of energy efficiency which can still be associated incorrectly with a lowered standard of output.

It should be noted that energy efficiency is not the only driver of energy productivity as measured at a national level. This is also driven by the structure of industry and the economy as a whole. A shift in the economy to a greater proportion of services compared

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[2] *Sustainable Energy For All 2015*

to industry, or a shift from heavy to lighter industry, will lead to an increase in energy productivity without necessarily an improvement in energy efficiency at the level of individual processes. Research shows that in general about 50% to 60% of improvements in energy productivity can be assigned to improvements in energy efficiency. In practice this will depend on a nation's economic structure and stage of economic development (Ehrhardt-Martinez et al. 2008).

The potential for increasing energy productivity is high. Exploiting that potential is consistent with economic growth. According to **The 2015 Energy Productivity And Economic Prosperity Index** (Blok et al. 2015), the world's six largest countries were able to generate an average of 18% of their GDP in the last ten years due to energy productivity improvements. The global average improvement was just 12%. The report's authors advised that to take advantage of the opportunities of producing more with less, "policy makers should be prepared to set ambitious targets, use their power of persuasion and promote the benefits of transition on a consistent basis". The authors concluded:

> "All regions of the world could improve their energy-productivity performance dramatically based on more aggressive adoption of existing technology. For the developing world, there is a chance to "leapfrog" the developed world and move speedily towards cost-saving energy-productivity levels. For the developed world, we believe Europe alone could see an economic expansion of 35% by 2030 and cut its energy use to 30.1 exajoules per year, a 35% improvement on current levels even while the economy grows at a healthier pace. The forecast is based on current energy use in Europe, rapid deployment of existing technology and economic projections from the European Commission."

3.2.2 Energy conservation

Energy conservation is another term that became popular after the oil crises of the 1970s and is still sometimes used in discussions of energy efficiency. It most commonly refers to reducing or stopping an energy using activity, such as switching off a light or a machine or driving fewer kilometres. Although there are undoubtedly occasions where this is a positive option, the term may still have negative connotations among non-specialists because of the implication that using less energy means doing less or making a sacrifice. These connotations are counter-productive when promoting the advantages of improving energy efficiency. The term should therefore be avoided.

3.2.3 Energy management and energy managers

Another term that we will use is energy management. Energy management is the set of management processes and tools to manage energy demand within enterprises, i.e. managing the process of improving energy efficiency, managing energy costs and managing energy risks. Since the 1980s, energy management has evolved as a separate management speciality. Strengthening energy management capacity within enterprises should be a major target of energy policies everywhere.

3.2.4 The relationship of efficiency to renewables

The use of renewable energy sources should not be considered to be energy efficiency at the level of individual facilities or processes. They are simply an alternative source of energy supply which may bring economic and greenhouse gas emission-reduction benefits in particular situations and jurisdictions. Their use does not improve the underlying efficiency of any particular end-use process.

Nevertheless they can help to improve the overall efficiency of an energy supply system and help to tackle climate change. For example, this can come about when the use of renewables such as solar in the electricity system has the effect of reducing peak loads (e.g. using distributed solar power in hot climates where there are high levels of air conditioning). This avoids additional, and usually the least efficient, power stations being kept on hot standby and being ramped up to meet peak loads.

Sometimes there remains confusion between renewables and energy efficiency. In the right framework, both can contribute to achieving energy cost, security and environmental objectives. But many studies have shown that improving end-use efficiency is cheaper on a price-per-energy-unit basis than installing renewables. Therefore energy efficiency should be implemented first.

3.2.5 Demand response and distributed generation

Two other areas related to energy efficiency are demand response and distributed generation. An example of distributed generation is Combined Heat and Power (CHP) (also called cogeneration). Demand response is the short-term shifting of electrical load to reduce stress on the electrical system, which in some jurisdictions is encouraged by incentive schemes. Again, strictly this is not energy efficiency but, like the use of renewables, the use of demand response may improve the overall efficiency of the electricity system by avoiding bringing inefficient power stations into operation for short periods to meet peak loads.

Table 2. Definitions of energy terms

Energy	Electricity, fuels, steam, heat, compressed air, and other similar media.
Energy use	The manner or type of application of energy.
Energy consumption	The quantity of energy used.
Energy efficiency	Formally the ratio between energy input and energy output but usually used to mean energy performance.
Energy performance	The ratio between delivery of an output e.g. production output and energy input.
Energy conservation	Reducing energy use by reducing or stopping an energy using activity e.g. switching off a light or a machine.
Energy management	The set of processes and tools to manage energy demand within enterprises i.e. managing the process of improving energy efficiency, managing energy costs and managing energy risks.
Energy intensity	Energy use per unit of Gross Domestic Product e.g. toe/USD 1000 of GDP.
Energy productivity	Gross Domestic Product per unit of energy input – the inverse of energy intensity.

To sum up, it is possible that the confusing legacy of the term “energy efficiency” and energy efficiency policy in itself acts as an impediment to effective action, both at the level of enterprises and at the level of national policy makers. Selecting, defining and promulgating the appropriate language should be one aim of policy makers.

In this book we will continue to use energy efficiency, since it is a common phrase. But readers should note the all-encompassing meaning, i.e. energy performance or energy productivity.

3.3 What do we mean by the potential for energy efficiency?

Over the last thirty to forty years there have been many studies on the potential for improving energy efficiency covering the global economy, regions, countries, economic sectors and industrial sub-sectors. One of the problems in evaluating potentials is that the many studies use different methodologies and different definitions of potential. It is important to distinguish between the main types of potential for improved energy efficiency. These can be broadly defined as follows:

- **economic potential** – the potential that is possible using available technologies that are cost-effective. It should be noted that the issue with this definition is that cost-effective has to be defined in relation to individual investors’ definitions of economic and therefore normally a standard definition is used – as in the McKinsey studies of potential such as McKinsey (2010).
- **technical potential** – the potential that is technically possible with best available technologies but no consideration of economics.
- **theoretical potential** – the potential that is possible using theoretical limits with no regard to whether the technology actually exists.

In reality all potentials are dynamic and are affected by shifting technological and economic factors. If energy prices rise the economic potential for energy efficiency increases. If energy prices fall it shrinks, all other things being equal. If the price of an energy efficient technology, such as an LED lamp, falls, then the economic potential for energy efficiency increases. Similarly, if a new energy efficiency technology is commercialised the potential increases. Potentials are also affected by management culture and systems, and by creativity. Two engineers looking at a particular industrial process for instance may come up with two very different solutions depending on their approach and creativity. An integrated design approach may well identify much larger economic potential than a traditional design approach.

3.4 Studies of the potential for energy efficiency in industry

As mentioned above there have been many studies on the potential for energy efficiency. What is clear from all of the studies is that there is a very significant potential to improve industrial energy efficiency using existing, proven technologies that are cost-effective today. The development of new technologies, the reduction of the price of the technologies, or increases in the price of energy will grow this potential.

Table 3. Savings from Adoption of Best Practice Commercial Technologies (Primary Energy Equivalents)
Source: IEA, 2007. Tracking Industrial Energy Efficiency and CO_2 Emissions.

	Low – High Estimates of Technical Savings Potential	
Sectoral Improvements	**Mtoe/year**	**Mt CO_2/year**
Chemicals/petrochemicals	120 – 155	370 – 470
Iron and steel	55 – 108	220 – 360
Cement	60 – 72	480 – 520
Pulp and paper	31 – 36	52 – 105
Aluminium	7 – 10	20 – 30
Other non-metallic minerals & non-ferrous	12 – 24	40 – 70
System/life cycle Improvements		
Motor systems	143 – 191	340 – 750
Combined heat and power	48 – 72	110 – 170
Steam systems	36 – 60	110 – 180
Process integration	24 – 60	70 – 180
Increased recycling	36 – 60	80 – 210
Energy recovery	36 – 55	80 – 190
Total	**600 – 900**	**1,900 – 3,200**
Global improvement potential – share of industrial energy us and CO_2 emissions	**18 – 26%**	**19 – 32%**
Global improvement potential – share of total energy use and CO_2 emissions	**5.4 – 8.0%**	**7.4 – 12.4%**

Research by the University of Cambridge (Cullen et al. 2011) and the Fraunhofer Institute for Systems and Innovation Research (Chazan 2013) found up to 73% of energy consumption can be avoided using current techniques, know-how and technologies. In addition, McKinsey & Company estimates, conservatively, 10% - 20% of energy savings comes from operational improvement efforts and investments in energy efficiency boosts the energy savings to 50% or more (McKinsey 2015).

An analysis by the IEA concluded that manufacturing industry can improve its energy efficiency by between 18 to 26% based on commercial, cost-effective proven technologies (IEA 2007). This study covered sectoral improvements, those that applied to specific sectors such as chemicals and petrochemicals, iron and steel, cement, pulp and paper, aluminium and other non-metallic minerals, and those technologies that could be applied across all sectors. The results are summarised in Table 3.

Table 4. Selected industry energy benchmark data
Source: UNIDO, 2010

Sectors	Units	Developed Countries	Developing Countries	Global Average	Lowest Found	BAT
Petroleum refineries	EEI	0.7 – 0.8	1.3 – 3.8	1.25	–	1.0
High value chemicals	GJ/t	12.6 – 18.3	17.1 – 18.3	16.9	12.5	10.6
Ammonia	GJ/t	33.2 – 36.2	35.9 – 46.5	41.0	31.5	23.5
Methanol	GJ/t	33.7 – 35.8	33.6 – 40.2	35.1	30.0	28.8
Alumina production	GJ/t	10.9 – 15.5	10.5 – 24.5	16.0	7.8	7.4
Aluminium smelting	MWh/t	14.8 – 15.8	14.6 – 15.0	15.5	14.2	13.4
Copper	GJ/t	–	–	13.8	7.4	6.3
Zinc	GJ/t	15.2 – 19.7	16.7 – 37.2	23.6	15.2	–
Iron and steel	EEI	1.2 – 1.4	1.4 – 2.2	1.5	1.16	1.0
Clinker	GJ/t	3.3 – 4.2	3.1 – 6.2	3.5	3.0	2.9
Cement	kWh/t	109 – 134	92 – 121	109	88	56
Lime	GJ/t	3.6 – 13.0	5.0 – 13.0	–	3.2	–
Glass	GJ/t	4.0 – 10.0	6.8 – 7.8	6.5	3.6	3.4
Brick making	MJ/kg	1.5 – 3.0	0.8 – 11.0	–	0.8	–
Tiles	GJ/t	1.9 – 7.3	3.1 – 8.3	–	1.9	–
Sanitaryware	GJ/t	4.2 – 11.3	4.4 – 20.0	–	4.2	–
Pulp and paper	EEI	0.9 – 1.7	0.4 – 2.3	1.3	–	1.0
Textile spinning	GJ/t	3.5 – 3.6	3.5 – 3.6	–	3.4	–
Textile weaving	GJ/t	11.0 – 65.0	5.0 – 43.0	–	–	–
Brewery	MJ/hl	–	–	229	156	–
Cheese	GJ/t	4.3 – 35.2	–	–	1.8	–
Fluid milk	GJ/t	3.1 – 6.5	–	–	0.3	–

The United Nations Industrial Development Organization (UNIDO) benchmarked the energy efficiency potential for 26 industrial sub-sectors in 2010 by looking at sector specific indicators of performance in terms of energy per unit of output (UNIDO 2010). The study broke down the results in developing and developed countries and also presented figures for the global average, the lowest found in the sample, and the achievable performance using Best Available Technology (BAT). The findings are comparable to those of the IEA, with an average savings potential of 26% of industrial energy usage. They are summarised in Table 4.

Based on these findings, industrial energy efficiency in developed and developing countries can be improved considerably by applying existing and economic technologies and improved management. Taking the estimated industrial energy consumption of 4,871 mtoe in 2035 and a conservative 20% energy savings potential, 974 mtoe could be saved. Table 4 shows that there is significant potential to improve energy efficiency just by bringing low performing industrial sectors up to the current average performance. This does not require new technology or even necessarily achieving BAT levels of performance.

Although studies of potential can only ever provide estimates, and are subject to considerable variations due to differing definitions of potential and constantly changing economics and technologies, it is clear that in all sectors of all economies, including industry, there remains a significant potential for improving energy efficiency through utilisation of existing technologies at rates of return that attract investment. In almost all sectors in all countries, there is a considerable gap between what is being achieved and the economic potential. Closing this gap should be a priority for policy and programmes.

The meaning of Best Available Techniques

Policy should refer either to Best Available Techniques Not Entailing Excessive Costs (BATNEEC) or, preferably, Best Available Techniques. The latter was incorporated into Europe's Integrated Pollution Prevention and Control (IPPC) Directive in 1996, replacing BATNEEC. Difficulties arise because both concepts require interpretation and devolve potentially controversial decisions to the level of the individual site regulator. They must balance the relative importance of environmental cost-benefit analysis versus the ability of a sector to 'afford' environmental improvements. Policy must address how regulators, who lack resources and depend upon industry for information, can function effectively. Best Available Techniques is a flexible concept, as what is currently regarded as "reasonably achievable", "best practicable" and "best available" may change over time. Policy should give guidance on this.

In Europe, Best Available Techniques for a given industrial sector are described in reference documents as defined in article 3(11) of the Europe Union's Industrial Emissions Directive. These documents are derived from extensive and controversial negotiations between European Union Member States, the industry-representing bodies, non-governmental enterprises promoting environmental protection and the European Commission. The process is ultimately steered by the Institute for Prospective Technological Studies of the European Commissions' Joint Research Centre, which is based in Seville, Spain. The process is described in detail in Commission Implementing Decision 2012/119/EU[3].

In the USA, the corresponding legal term is Best Available Control Technology (BACT). It is also a pollution control standard mandated by the country's Clean Air Act. The technology covered by the term is decided by the U.S. Environmental Protection Agency (EPA), again in consultation with stakeholders, based on factors such as energy consumption, total source emission, regional environmental impact, and economic costs.

[3] *Commission Implementing Decision 2012/119/EU of 10 February 2012 laying down rules concerning guidance on the collection of data and on the drawing up of BAT reference documents and on their quality assurance referred to in Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012D0119&from=EN*

The concept also appears in other pollution control legislation around the world. In all cases the standard is lower than the most efficient achievable control technology. Criticism of the Best Available Techniques approach is also based on the time lag between a new and better technical solution coming onto the market and it being incorporated into regulatory practice.

3.5 Is there a limit to energy efficiency?

It is worth considering the question: is there a limit to how far we can improve energy efficiency – in other words could we "run out" of energy efficiency opportunities? For any energy conversion process – whether it be electricity to light or fuel to motive power, there is a fundamental limit set by the laws of thermodynamics. In practice no real-life technology can reach that limit. It is meaningless to talk about a limit for passive systems such as buildings, since we have known for a long time how to build zero energy buildings. The "efficiency" – or more properly performance – of passive systems depends on practical engineering, industry custom and practice, and cost constraints rather than underlying physics.

When considering the whole global economy Cullen et al. (2011) concluded that the existing economy could run on 73% less energy by applying known engineering best practice to passive systems that transform energy into services such as buildings. They also estimated the energy reduction potential in conversion devices to be 85% without any reduction in service levels. They concluded that globally, we use 475 exajoules (EJ) of primary energy resources (oil, coal, biomass, renewables and nuclear) to provide 55 EJ of useful energy services (motion, heat, cooling, light and sound). This means that globally we have achieved an overall energy efficiency of just 11%.

All the evidence is that the energy efficiency resource is extremely large and is unlikely to run out in the foreseeable future. To support this view, many industrial enterprises have continued to achieve high levels of energy savings over a long period of time. Work by the Next Manufacturing Revolution, showed that there are many enterprises that have achieved consistent and high levels of energy savings year-on-year for more than ten years (Lavery et al. 2013). Numerous examples from various industrial sectors demonstrate that companies in all sectors can continue to achieve energy savings over a long time. One of many companies that have continually improved energy efficiency over many years is Owens Corning.

Industrial case study: Owens Corning

Owens Corning, an international manufacturer of insulation and related building products, embarked on an energy efficiency programme in 1999 by declaring a target of reducing energy costs by 20%. In 2001 the company formed an internal energy services company and introduced simple measurements of performance to each department and encouraged ideas for improvements through competitions and awards. In 2003 the company reduced annual energy costs from USD 260m to

USD 220m and yet invested less than USD 20m into energy efficiency projects, i.e., many of the measures were no or low cost. In this period production increased by 18% and energy prices rose by 10%. Three quarters of the gains were achieved from measures identified and implemented by employees. The highest performing units also had the highest quality and safety, and the lowest waste levels. After this period the company relentlessly pursued energy efficiency – setting a target of achieving a further 30% improvement in energy productivity in pilot plants.

Between 2002 and 2011 company-wide energy intensity reduced by 20% and absolute energy use was reduced from about 11 million MWh to about 8.5 million MWh. The company is targeting a further 20% reduction in energy intensity to 2020 relative to the 2010 achievement. Owens Corning is not alone in achieving continuous improvement over many years and even decades. IBM – the global computing giant, which has been implementing energy savings since 1974, can still find energy saving opportunities with a two-year payback (Henderson et al. 2009). Other industrials with impressive track records in this regard include Dow Chemicals and 3M, both of which operate inherently energy-intensive processes.

3.6 Comparing the energy efficiency resource to oil and gas resources

Increasingly analysts are recognising that the potential for energy efficiency is analogous to conventional energy resources and reserves. Recognising this equivalence of energy efficiency to energy resources has not yet been universally accepted, but in itself this change in mind-set may be vital for the future of energy efficiency. Efficiency has sometimes been labelled "the fifth fuel" (after oil, coal, gas and electricity) but the European Union and IEA have recently called efficiency the 'first fuel', marking a considerable shift in emphasis.

The analogy between the potentials for energy efficiency and the potentials for fossil fuels or other energy sources such as wind power is worth exploring briefly[4].

The methodology for defining and measuring resources and reserves is called the Petroleum Resources Management System (PRMS) (Society of Petroleum Engineers et al. 2011) and has been developed by the Society of Petroleum Engineers and endorsed by the World Petroleum Council, the American Association of Petroleum Geologists, the Society of Petroleum Engineers and the Society of Exploration Geophysicists. The valuation of oil and gas companies is based on the use of the PRMS. When oil and gas companies come to the public markets the price is related to the PRMS assessment as it provides a standardised way of assessing, and therefore valuing, resources and reserves. Within the PRMS oil and gas resources are defined as either reserves, contingent resources, undiscovered petroleum initially-in-place or prospective resources.

[4] *For a fuller exploration of the analogy see: http://www.onlyelevenpercent.com/energy-efficiency-as-a-resource/*

Energy efficiency reserves, using the PRMS criteria of being discovered, recoverable, commercial and remaining, are those projects that have been identified in some process (probably involving an energy audit), that can be implemented practically, that are commercial according to the investor's criteria, and that are not yet implemented.

It is often said that one of the problems with energy efficiency is that it is 'invisible'. We should not forget that oil and gas resources and reserves are also invisible. They are revealed by the tools of geology and seismic studies – which are increasingly sophisticated. Correspondingly, it is tools like benchmarking and energy audits that reveal the available energy efficiency resource. Many years of energy audits have identified economically viable projects which have not been implemented – energy audits are notorious for sitting on the shelf (or these days on the hard drive). The projects identified in those audits are effectively energy reserves just like oil and gas reserves.

Policy makers should therefore consider energy efficiency potential as a resource akin to any other energy resource and give it equivalent consideration.

3.7 The rebound effect

Any discussion of energy efficiency would not be complete without the mention of Jevons paradox (also known as the 'rebound effect' or 'Khazzoom-Brookes postulate' (Gavankar et al. 2011)). William Stanley Jevons argued, in his 1865 book *The Coal Question*, that the effective and efficient use of energy leads to an increase in energy consumption. In his words:

> "it is a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth....."

The paradox is sometimes held up as a reason for policy makers not support the improvement of energy efficiency, but this reflects a misunderstanding of exactly what it is and why it is important. It has sparked off considerable debate within energy policy and analysis circles at regular intervals over the last forty years.

Increased energy efficiency tends to increase energy consumption by two means. First, increased energy efficiency makes the use of energy relatively cheaper, thus encouraging increased use (the direct rebound effect). Second, increased energy efficiency leads to increased economic growth, which pulls up energy use for the whole economy (the indirect effect).

One thing is clear: while Jevons paradox is an interesting subject, it has little relevance to individual enterprises. Even if overall energy consumption rises due to increased sales, overall energy, and hence cost, per unit of output would have been reduced by the improvement in energy efficiency.

At a national level, energy consumption figures and energy intensity figures are the net of energy savings by all enterprises in the country less the energy consumption increase due to economic growth. The rebound effect is relevant to national energy planners and for rapidly developing countries the rebound effect is likely to be larger than in developed economies as they still have much pent up demand for goods and services, whereas in more mature economies there is a higher degree of saturation.

Although knowledge and understanding of Jevons paradox is useful it should not unduly influence energy efficiency policy.

3.8 Conclusions

It is important that policy makers understand the true nature of energy efficiency at company and national levels and the scale of its potential. It is also important that policies designed to improve energy efficiency in industry, or indeed in other sectors, are based on and promote a common understanding. The potential for improved energy efficiency with existing, mature and cost-effective technologies, which is now widely recognised, is in the range of 20 to 30% of total industrial energy use. Viewing energy efficiency as a resource in a similar way to conventional oil and gas or other energy resources is a useful approach, although one not yet widely accepted by energy policy makers.

Chapter 4 looks at both the management processes, and the technologies that can enable industrial enterprises to achieve higher levels of energy efficiency and thereby exploit more of the efficiency resource.

Key points:

- Energy efficiency is measured as the ratio between the useful output of the end-use service and the associated energy input.
- Energy efficiency in every day usage really means energy performance.
- Improving energy efficiency is a process of technical and behavioural change that is driven by technological, financial, management, social and policy drivers and constraints.
- All regions of the world could improve their energy-productivity performance dramatically based on more aggressive adoption of existing technology.
- Energy efficiency should be viewed as an energy reserve just like fossil fuel reserves.
- Manufacturing industry could improve its energy efficiency by 18 to 26% based on commercial, cost-effective proven technologies.
- Industrial enterprises can improve energy efficiency continuously over many years and decades.
- The rebound effect should not inhibit more aggressive actions on industrial energy efficiency.

CHAPTER 4.

The Management and Technology of Improving Energy Efficiency in Industry

'Management is doing things right; leadership is doing the right things.' 'What is measured improves'.

– Peter F. Drucker, Management consultant, educator and author, 1909–2005

4.1 Introduction

This chapter is a brief introduction to both the principles of energy management and key energy efficiency technologies in industry. Understanding the most effective management processes to improving efficiency is important for policy makers because extending the application of sound energy management should be the foundation of any industrial energy efficiency policy. Policy makers also need an appreciation of the available technological options to improve efficiency, all of which are well proven and mature. We have included this description of the main technologies here for completeness but non-technical readers may want to pass over this section. They should take away the key message that these are all well proven, mature technologies that will be economically viable in many specific sites.

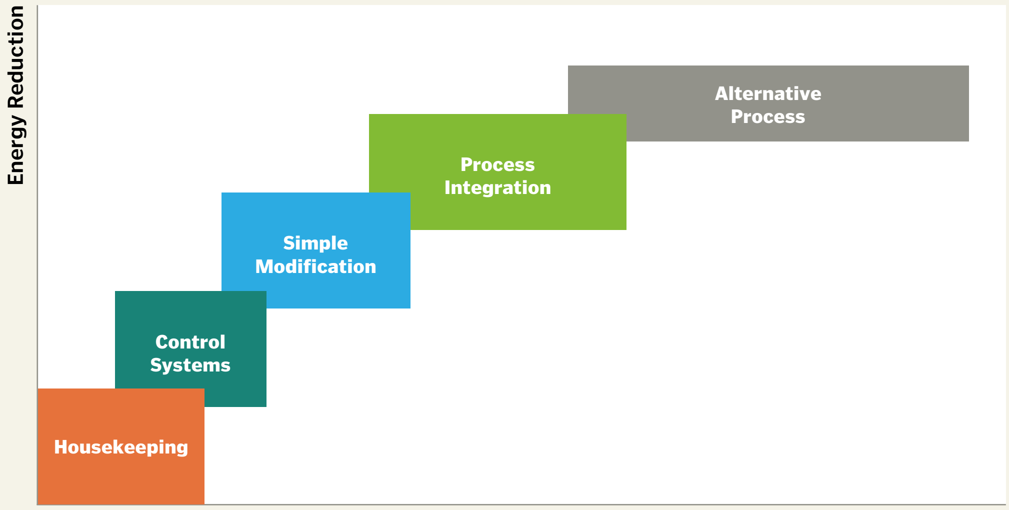
4.2 Energy management as a discipline

Energy management as a definable management discipline began to emerge in the 1970s and 1980s after the oil crises of 1973/74 and 1979. Enterprises appointed energy managers to combat the significant rise in energy prices that occurred in those periods and over time a management approach and discipline was defined and codified. Improving the energy performance of any particular industrial process (or building) involves technical issues but is really a management problem. Many cost-effective energy efficiency technologies exist across all industries – applying them requires management.

The following are recommended features of an effective energy management system:

- Use consistent and simple language
- Involve the whole firm, not just engineering or technical departments
- Allocate clear responsibilities and resources
- Create a culture in which established assumptions can be challenged
- Integrate energy management into daily operations
- Use appropriate performance measurements and feedback loops

Figure 3. Energy maturity model
Source: Adapted from Oung, K., 2013.



- Integrate energy efficiency into life cycle decisions about new plant and equipment
- Aim for continual improvement
- Set stretched but achievable objectives with periodic reviews.

Together, these features bring focus and structure for top management and all employees of enterprises to be actively involved in bringing about continual improvements in energy efficiency.

4.3 A structured approach to energy management

Improving energy efficiency in industrial facilities needs to be done within the context of an energy management system (EnMS). Energy management systems are purely management systems and should be distinguished from electronic based Building Management Systems (BMS) or similar control technologies.

Within any EnMS in an existing plant, the best way to maximise the quantity of energy savings and minimising investment cost is to follow a five-stage process based on the energy maturity matrix shown in Figure 3.

4.3.1 Good housekeeping

The first step is to prioritise housekeeping opportunities. Frequently, the opportunities that cost little or nothing include: implementing good maintenance, turning things off when they are not needed, reinstating and improving insulation and air leakage, reducing waste, leaks, idle time, production rate losses, and turning off taps and hoses when not needed. The benefit from steadfast and zero tolerance in good housekeeping is a reduction of energy consumption and this can reduce the size and capital investment of subsequent energy-saving opportunities.

Many housekeeping opportunities exist in the operation of industrial plants. Energy losses can present themselves as: pressure loss (drop), heat loss or gain, process waste such as blow-down, vent, drain, samples, reject, exhaust, fluid loss (leaks), friction or slippage, simultaneous heating/cooling, electrical losses, and using more than necessary for the application.

Individual housekeeping opportunities may be small, and as such are frequently ignored, missed or not prioritised. In some companies, these opportunities are side-lined in preference for larger energy saving opportunities but the sum of these opportunities, while individually are small, can represent a big opportunity. For example, a water leak of one drop per second is equivalent to 0.5 litre per minute – a tiny opportunity. A small site with 100 'one drop per second' leaks is losing 50 litres per minute. The effort, cost and business risk for addressing these opportunities are small.

Simple processes can be instilled and implemented within an organization to address housekeeping issues. The eight focus areas relevant to operational and maintenance matters are:

- Ensure ample time for good quality maintenance to be carried out and completed. Points to consider: maintenance according to guidelines, a routine inspection and maintenance schedule, use of the correct (and latest, most efficient) parts, ensuring the work is carried out by competent personnel.
- For recurring plant failures, ensure that the root causes are identified and/or the issue designed out. Points to consider: ensuring that everyone contributes to uncovering the root cause, conducting experiments and tests, ensuring that a root cause is addressed effectively without introducing another issue elsewhere.
- Ensure that all equipment is installed correctly as described in the user manual and as designed. Points to consider: requesting installation information from the supplier before purchasing, reviewing the design to ensure recommended design requirements are met, reviewing the actual installation to make sure it is as per design, allowing time during installation to review, ensuring all issues are satisfactorily addressed before handover.
- Ensure that all equipment is sized to match actual demand with minimal excess capacity. Points to consider: ensuring the minimum, normal and maximum operating requirements are known and/or established, ensuring that equipment specification meets the operation requirements without excess capacity.
- As far as practicable, verify that all equipment can be turned off safely when not required. Points to consider: ensuring there are isolation valves, ensuring arrangements to make safe the plant and machinery, ensuring plant and machinery can be reinstated at short notice.
- When there is a choice of machines, operate the machine that meets the demand at the highest energy efficiency. This ties in with awareness of the minimum, normal and maximum operating conditions.

- As far as possible, minimise idle time. Points to consider: stopping machines as soon as possible, starting as late as possible, and find opportunities to minimise product change over times and/or production handover times.
- Ensure all insulation is in good condition and draughts are eliminated.

Embedding good housekeeping within organizations requires involving employees at all levels. This means raising awareness and working to engage all staff. Effective energy management systems are not just technical programmes run by a few specialised personnel.

4.3.2 The use of control systems

The introduction and tightening of the control systems of existing processes and utilities can further dampen variation in energy consumption and allow a process to operate closer to its designed control limits. Some small investment may be necessary to repair, reinstate, replace and/or introduce new control parameters. There are many examples falling into the control systems category, including:

- introducing temperature control limits in air conditioning systems
- matching the most efficient machine with actual demand
- using preventive maintenance and condition monitoring to predict and prevent equipment failures
- improving the consistency of water chemistry
- reducing excess flows
- increasing cycles of concentration
- reducing blow down
- using variable speed drives
- utilising control loop tuning
- monitoring the performance of key plant items.

Housekeeping and control system improvements are normally carried out at individual equipment and machinery levels. The next level of complexity involves looking at energy savings from a unit operations or systems perspective.

4.3.3 The need for systems thinking

Energy use, particularly in industrial sectors, occurs in systems in which several energy using components are interconnected, via pipes and electric cables, in a coherently organised way.

Applying systems thinking in energy savings projects can brings about large savings. Studies by UNIDO, US DOE (US Department of Energy 2004b) and IEA (2007) have shown that applying systems thinking to motor systems and steam systems can save between 10% and 20% versus an equipment-only saving of between 2% and 5%.

At the lower end of systems optimisation are simple modifications and/or refurbishments. Examples of simple modifications include: using compact heat exchangers, utilising closed-loop systems, heat recovery, pipe work and pumps, waste heat recovery boilers, pre-heaters and economisers, and the use of energy efficient components in a machine such as variable speed drives to match supply with demand.

Integration of energy use is a more complex form of plant modification and retrofit but gives further energy savings. Some example includes: recovering heat from one process to be reused in another process, thermal pinch analysis, process intensification, de-bottlenecking and uprating, and overall plant or site-wide optimisation to minimise overall energy consumption.

4.3.4 Step changes in process design and/or energy supply

The highest form of energy maturity, giving the biggest energy savings, comes from a step change either in process design, energy supply, or both. This is the most costly and carries the highest business risks compared to other projects in the energy maturity matrix. Examples include:

- combined heat and power plants
- refitting the production line with a new process technology
- applying dynamic simulation and predictive controls
- extending the energy or waste heat into a district heating and/or cooling network.

Engineering and technical staff are naturally inclined towards the most complex opportunities. However, the implementation of high-end projects requires specialist knowledge and skill. It also carries higher business risks, costs more, and may straddle across several organizational boundaries. Initiatives at the lower level require less specialised knowledge and skill to implement. Enterprises should always start energy management programmes at the housekeeping level and move through the maturity matrix.

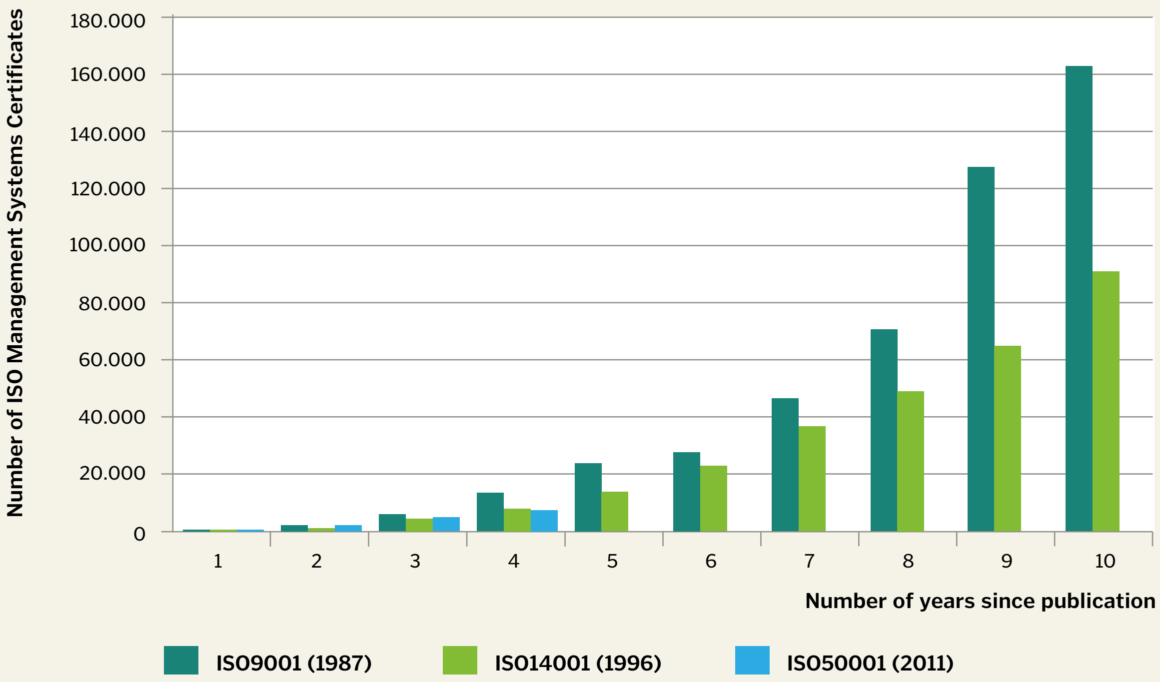
Again, referring to the findings from Cullen (2009) and McKinsey (2015), 10% - 20% of energy savings can come from exploiting lower level energy use and energy consumption opportunities. The remaining can come from implementing higher-level opportunities.

When designing new plants and systems, carrying out plant expansion and/or major refurbishing and retrofits, elements from the energy maturity matrix can be incorporated into the designs. Where there is an existing plant, lessons learnt from plant operation and maintenance can be incorporated.

4.4 Standardising energy management systems through ISO 50001

Many tools and models of the energy management process have been developed. Most of these draw on wider models of management decision-making and management of technological change. They have been proven to be practical across all sectors and continue to be useful but to a certain extent have been overtaken by the launch of the International Standard ISO 50001, "Energy Management" (ISO 2015).

Figure 4. Adoption of ISO 50001 compared with ISO 9001 and ISO 14001
Note: ISO 50001 data for year 4 is for six months only, data for the full year is not available.
Source: Oung, K., 2014.



ISO 50001 was developed by an international group of experts and launched in 2011. Its application globally is growing rapidly. Figure 4 shows its global adoption in the first four years since its launch in comparison to two other popular standards: ISO 9001 'Quality Management' and ISO 14001 'Environmental Management'.

In the words of the International Standards Organization (ISO) itself:

> "ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management.
>
> ISO 50001:2011 provides a framework of requirements for organizations to:
> - Develop a policy for more efficient use of energy
> - Fix targets and objectives to meet the policy
> - Use data to better understand and make decisions about energy use
> - Measure the results
> - Review how well the policy works, and continually improve energy management."

ISO 50001 is the first internationally recognised standard to set out an integrated set of processes and tools to help enterprises implement an effective energy management system. By choosing to adopt ISO 50001, senior management can make a clear and visible commitment to having a systematic energy management programme and ensuring that appropriate systems and standards are in place. ISO 50001 starts with the need to have a high-level strategy and goes onto operational level activities such as monitoring and targeting energy use. It uses the Plan-Do-Check-Act (PDCA) approach.

ISO 50001 is a significant step forward in energy management and should be the centrepiece of policies to improve industrial energy efficiency. It places emphasis on management systems which can be operated by people who may not have a technical energy background or who may be entering the discipline for the first time.

The foundation of any policy to improve industrial energy efficiency should be the promotion of sound energy management systems and we will examine case studies of this in subsequent chapters. The development of ISO 50001 provides a standardised, international approach to best practice which can be applied in all countries and across all sectors. It provides a framework to help build energy management capacity within enterprises, industries and the economy as a whole. Examples of policies to promote energy management systems and in particular ISO 50001 will be given in Chapter 7.

4.5 Measurement and Verification (M&V)

Policies should promote the use of measurement and verification (M&V) systems. M&V of energy use is a key part of any energy management programme. It is essential in order to judge whether energy efficiency projects have delivered the planned results. A good M&V plan defines the methods and techniques that will be used to determine savings resulting from specific energy efficiency projects. The plan may include:

- Goals and objectives, with key performance indicators, such as the energy, cost and carbon emission savings expected
- The scope and nature of the work
- Techniques to be used for each energy efficiency opportunity
- Key physical characteristics of the facility, system and measure
- Critical factors that affect energy consumption of the system or measure
- Baseline performance characteristics, such as flows, temperatures and hours of operation
- Sampling protocols
- Reporting the outcome.

There are many protocols and patents for measurement and verification available in the market. One protocol, originally developed under the auspices of US Department of Energy (now promoted globally by the not-for-profit organization Efficiency Valuation Organization – EVO) is the International Performance Measurement and Verification Protocol (IPMVP). Other M&V protocols, can be scheme specific and the compliance with the scheme requires the use of scheme-specific protocols. Policies should promote the use of M&V systems.

4.6 Technologies for energy efficiency

This book is not the place for a full exposition of all the technological options for industry to improve energy efficiency. It is unlikely that any one volume could ever cover all the possibilities and there are many guides to appropriate technologies across multiple sectors (see for example: Thumann et al. 2013, Institute for Industrial Productivity 2009, Lawrence Berkeley Laboratory 2007, Fawkes 2013 and Thorpe 2014). However, having a broad understanding of the main technological options that are available to industrial energy users is important for policy makers. Some readers may skip this section but all readers should understand that in all industrial sectors there are well proven and mature energy efficiency technologies, and that some of these technologies can be applied in all sectors, e.g. high efficiency electric motors.

4.6.1 Motors and driven systems

Electric motors are ubiquitous throughout all industries. They can be found on pumps, fans, compressors and drives, and are usually part of a larger system, such as a process plant or an air-conditioning system. In such a case we can either talk about the efficiency of the whole system or of the motor itself. In total, around the world, motors account for about 60% of industrial electricity consumption, consuming 406 mtoe. The IEA (2007) estimates that 143 - 191 mtoe of savings can be achieved by making improvements to motor systems.

There are several ways in which major energy savings in motors and motor driven systems can be achieved. These are described below.

Existing motors

Motors should be turned off when they are not in use. Since these motors can often be hidden away inside other equipment, they can easily be overlooked and left running when they are not needed, leading to unnecessary energy use and cost. An energy audit should identify such situations and develop strategies to remind people to switch motors off, or specify controls to enable them to be switched off automatically when they are not required. In examining the efficiency of an entire production system, it may be possible to redesign a manufacturing process to minimise the use of the motor, or to maximise its effectiveness when it is running. For pumps in liquid, air or gaseous circulation systems, the use of sensors that switch off a motor when a certain level is reached can substitute for valves that control liquid or airflow but keep the motor running at all times.

But switching off is sometimes easier said than done. Two frequently cited reasons for not doing so, and possible solutions, are:

- “It drains the systems, thus it is difficult to re-start”: This is associated with keeping a pumped system ready for restart. For example, in an open vacuum pumping system, turning off the pump would result in the whole system losing its vacuum and needing to be re-established upon restart. Alternatively it may result in a fluid flowing backwards to the tank, requiring the pump to be re-primed upon restart. A simple solution may be to add isolating valves before and after the pump, allowing the system to be restarted by opening both valves.

- "It causes a hazardous situation": This is a matter of reviewing the design and safety systems to find a way to make the system safe and stop the pump, then evaluating the additional cost and benefit of stopping the pump.

In a pipe or a duct every obstruction to the flow of a fluid or gas – caused by valves, bends, baffles and friction – requires a pump or fan to work harder. These should be overcome by re-design wherever possible.

Sometimes pumps in a fluid transfer system or air-conditioning system run continuously at a fixed level, with the flow controlled by baffles (a valve-like device used to restrain the flow of a fluid or gas). The baffles should be removed and the motor replaced with a variable-speed drive. To further optimise the system an appropriately-sized pump or fan should be selected along with pipework or ducts that are sized to minimise flow velocities and friction losses for the desired purpose.

Motor alignment

Pump and motor alignment can also be a source of energy inefficiency. A misaligned motor and pump can lead to premature failure. Studies have shown how correcting a misaligned motor and pump generated real power savings of 2.3% (Luedeking 2015) while losses from badly aligned motors can be up to 9% of total consumption (Lambley 1996).

Sizing of motors

Motors and pumps, like other industrial energy plant, are often over-sized. This leads to unnecessary financial penalties in terms of capital costs, energy costs and cost of maintenance. Over-sizing can be due to a number of reasons.

It may be due to equipment suppliers providing the biggest motor or pump that meets the flow duties, thus maximising the capital cost of the equipment. It could be due to unavailability of the best matched motors by the enterprise's preferred equipment supplier. If this is the case, a different equipment supplier or purchasing schedule might be chosen.

Another reason for over-sizing may be that designers or final specifiers added a design safety margin over and above other safety margins. Over-sizing can also be due to the misconception that swapping a motor for a bigger variant will increase its operating capacity. In practice, a motor will only consume sufficient quantities of electricity for the pump to operate. Designers and specifiers need to work hard to tackle the over-sizing of motors at every opportunity.

Use the most efficient motor

The fundamental efficiency of electric motors varies significantly and therefore the motor selected can have a major impact on energy efficiency even when correctly sized for the task. The cost of running an electric motor over its lifetime is hundreds if not thousands of times greater than its purchase price. For example, a 15kW IE3 motor (which is 92% efficient) running for 4,500 hours a year at 71% load consumes 44,091 kWh/year. Assuming electricity charged at USD 0.20/kWh that equates to USD 8,818 per year. If it lasted for 12 years it would cost USD 105,818 (not accounting for future increases in the price of energy). Assuming an initial cost for the motor of USD 1,000 it is easy to see that its capital cost is 1% of its lifetime cost. Therefore it makes sense to choose the right motor or drive for every purpose.

A range of motor efficiency standards has been established to assist enterprises in procuring the most efficient motors.

The European Union Directive 2005/32/EC on the Eco-Design Requirements for Energy-Using Products mandates energy efficiency classes for industrial electric motors. The European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) runs a voluntary programme of motor efficiency standards. Both refer to the International Electrotechnical Commission (IEC) motor efficiency classification international standard IEC60034-30. This gives a basic indication of efficiency for single-speed, three-phase, cage-induction motors with 2, 4 or 6 poles. It covers the vast majority of industrial motors: motors, geared motors and brake motors rated up to 1000 V, with two, four or six poles and capable of operating direct online, for continuous duty or operation on an 80% duty cycle or higher. To avoid confusion with previous standards both the efficiency class and efficiency value must be shown on the motor's rating plate and in its product documentation. Motors are classified by IEC according to their efficiency level as shown in Table 5.

A 2-pole 11 kW IE3 motor in continuous use will use almost 4% less energy per year than an equivalent IE1 model. Presently, under European Commission's eco-design directive, all motors sold in the European Community must be IE2 or better. From 1 January 2015, those rated between 7.5 and 375kW must at minimum be IE3 level or the IE2 level when sold with a variable speed drive. From 1 January 2017, this will also apply to motors right down to 0.75 kW.

The standard covers motors with a range of power outputs between 120W and 1,000 kW. The range of efficiency between IE1 and IE4 motors, depending on motor size and type, can vary by 5% or more. An IE5 level is envisaged for future use with the goal of further reducing energy usage compared to IE4 by 20%. In the USA, for 60 Hz operation, the

Table 5. The IEC classification of electric motors
Source: International Electrotechnical Commission, 2015

Label	Efficiency level	Notes
IE1	Standard efficiency	Efficiency levels similar to the existing European CEMEP Eff2 class.
IE2	High efficiency	Same as the US Energy Policy Act (EPAct) set minimum efficiency levels for 60 Hz, considerably higher than EFF2 of CEMEP for 50 Hz.
IE3	Premium efficiency	Higher than EFF1 on CEMEP for 50 Hz, in most cases identical to NEMA Premium in the US for 60 Hz.
IE4	Super premium efficiency	Higher than any other standard, not yet implemented.

IE2 and IE3 minimum full-load efficiency values are virtually identical to the National Electrical Manufacturers Association (NEMA) Energy Efficient and Premium Efficiency motor standards.

When purchasing a new motor or pumping application, the motor with the highest motor efficiency should be used. The purchasing specification should also specify the motor efficiency requirements. There is a view that more efficiency motors are more expensive than an inefficient motor but this is not necessarily the case in practice (Lovins 2007). The lifetime cost of operating a motor should be calculated to make a valid comparison with the capital cost. The return on the expenditure should be rapid even if there is an additional cost for a more efficient motor.

Motor efficiency is of even greater importance in industrial facilities than in commercial buildings. Free software called MotorMaster+ to enable the comparison of motor systems for energy efficiency is available from the US DOE's Efficiency and Renewable Energy Office[5]. A range of calculators for variable speed drives for fans and pumps are also available from the same source.

It is preferable to compare the numerical motor efficiency rather than the efficiency classification. This is because the category classifies motors into their thresholds. When there are two or more motors of the same classification, it will be the numerical efficiency number that will determine which is more efficient.

Often old motors are rewound rather than replaced. Although rewinding may not reduce efficiency (EASA & EAEMT 2003) it does prevent the gain in efficiency that would result from using a newer motor. Countries with Minimum Energy Performance Standards (MEPS) which prohibit the sale of new motors below a certain standard (discussed in Chapter 8) (e.g. New Zealand) have considered banning the rewinding of motors below 50 kW to avoid disrupting the mandatory introduction of new higher efficiency motors.

In general, replacing an existing motor with a higher efficiency motor purely for energy efficiency gains (i.e. if it wasn't broken) would not pay for itself within the typical expected financial payback period. However, there are exceptions to the rule, such as when a motor is very old, very inefficient, and/or significantly oversized. In such situations a case can be made for replacement with the most efficient model by combining reasons such as: renewing ageing assets, replacing with new rather than rewinding, and resizing to a smaller motor.

Maintenance issues

Motors should be subject to regular maintenance checks, which include checking the alignment of pulleys, belt condition and tension, lubrication and mountings, loose terminals, whether the supply voltage is within the specified allowed deviation from the motor's nominal rated voltage (+/−5% or so usually) and the line voltages are balanced to within 1

[5] *MotorMaster+ software available at http://1.usa.gov/HiaJ07*

per cent of each other. The most common type of motor is an AC induction motor. These usually run at a fixed speed and the most energy is consumed when a motor starts up.

Motors also generate significant heat and have cooling fins to dissipate this wasted energy. Running them at a higher temperature is inefficient and renders them more liable to failure. It is therefore important to keep the fins clean and ventilated, and to replace them if faulty.

Variable Speed Drives

Variable Speed Drives (VSDs) are a way of matching power supply to the required duty. Variable (or adjustable) speed drives convert the incoming electrical supply, which has a fixed frequency and voltage, into variable versions of both. This allows the motor speed to be varied from zero to its maximum rated speed, so it can match the actual power demand of the load. Correctly designed VSD systems can reduce energy consumption between 20% and 70% (ABB 2009). Retrofitting VSDs can, depending on the circumstances, have a payback period of less than 1 year.

It is estimated that between 50-70% of industrial processes would benefit from VSD. Yet the current penetration rate of VSD as a proportion of installed motors is still low. Evidence indicates that the highest levels have been achieved in the US, at nearly 20% (Lowe et al. 2010). The UK Trade Association for Automation, Instrumentation and Control Laboratory Technology puts market penetration of VSDs at a mere 10%, a level thought to be similar to in China. Other figures suggest that VSD penetration in Europe is no higher than 15%. Increasing the use of VSDs would make significant energy savings in all countries. Research by Siemens Financial Services indicated that if the full potential of variable-speed drives (VSDs) was implemented across 10 countries, (US, China, Russia, Germany, India, UK, Spain, France, Turkey and Poland), savings over the next five years would total EUR 56,404 million (Siemens 2012).

What other devices can benefit from VSDs? In general, there are three types of loads that can be driven by motors: constant power loads, constant torque loads and variable torque loads.

- For constant power loads a variable speed drive is not appropriate, as there will be no energy saving for any reduction in speed.
- For constant torque loads, which include centrifuges, conveyors, extruders, grinders, mills, mixers, screw and reciprocating compressors, crushers and surface winders, the power consumed is in direct proportion to the useful work done, so halving the speed will result in halving the power consumed. Other benefits include soft start-up of the equipment, reduced current on starting, reduced mechanical stress and high power factor.
- For variable torque loads, since the power consumed varies with the cube of the motor speed, any speed reduction on the part of the motor will result in large energy savings. A 20% reduction in motor speed can result in a 50% power saving.

Applications which benefit most from variable speed drives include:

- Centrifugal fans and pumps that do not need to run at full capacity all of the time
- Heating, Ventilation and Air Conditioning (HVAC) systems for areas where occupancy varies
- Heating and chilled water circulation pumps
- Air compressors (where the average load on the compressor is less than 75% and it is frequently off)
- Processes or systems driven by a centrifugal pump or fan where dampers and valves control the flow
- Extraction fans in dry areas
- Combustion air fans on large burners, where motorised dampers adjust the air to fuel ratio.

4.6.2 Steam systems

In industry, systems that provide process heat can be either direct-fired, steam based or hot water based. The choice is primarily dictated by the nature of the manufacturing process and the prevalent engineering custom and practice within the industry. In general, high-temperature applications such as steel, cement, ceramic, certain chemical processes and selected heat treatment processes are direct-fired. General energy-saving opportunities in direct-fired applications include: better control of the process, ensuring that processes are not running for longer than necessary to achieve the desired effect, maximising the utilisation of the heat, recovering energy from the exhaust gases, and reducing the amount of energy lost to the environment.

A significant majority of other industrial processes utilise steam as the energy carrier. These include: boiling, evaporating, drying, cleaning, sterilisation, selected chemical processes, and selected heat treatment. It is estimated by the IEA (2007) that 1,051 mtoe of fuel is utilised to generate steam and that this accounts for about 38% of industrial energy consumption.

A correctly designed and operated steam system typically loses 45% of input energy before doing its intended work (US DOE 2004a). Losses can occur in the boiler plant, boiler ancillary plants, distribution network and at the end use. The IEA (2007) estimates that energy improvements in steam systems can save between 36 to 60 mtoe annually. A number of technological options to achieve the potential savings exist and are well proven.

Minimise the number of heat transformations

Steam is generated in a boiler where the energy content of fossil fuel is converted into heat, which in turn is used to convert water into steam. At the present time, the thermal efficiency of a newly designed and built boiler is between 80% and 85% on a gross calorific value (GCV) basis (also known as higher heating value). Between 15% and 20% of the energy contained in the fuel escapes up the chimney (stack).

According to the law of thermodynamics, every time energy is transformed from one form to another, some energy is lost. In industry, especially in the low-temperature applications, steam is often used to generate hot water. To illustrate the effect of heat transfer on overall energy efficiency: assuming that both the boiler and a heat exchanger is 80% efficient, if a site generates steam and uses it to generate hot water, thermal energy is transformed twice. The overall efficiency becomes 80% × 80% = 64%. In some industry, for example the food industry, the hot water is often used to generate lower-temperature hot water. In such applications, the overall thermal efficiency becomes even lower.

The best way to save energy is to avoid transforming energy unnecessarily. Direct-fired equipment uses only one conversion process and if hot water is required it can be generated directly rather than via steam. Opportunities to minimise the number of heat transfer processes should be identified and explored. Although not always the case, it may transpire that it is cost-prohibitive to convert existing plant from steam-operation into hot water-operation due to the cost of new pipe networks for hot water. In such cases the idea and concept should be retained for future plant modification and/or new builds.

Preheat water and air

In a steam boiler, between 80% and 85% of the fuel energy is utilised to transform water into steam with 15% to 20% of the energy in the burnt fuel lost through the chimney. Depending on the fuel type, boiler construction, and controls, the hot exhaust gas from the boiler can be over 180°C. This hot exhaust can be utilised to pre-heat the boiler feed water, pre-heat the combustion air or both. Boiler feed water can be pre-heated in an economiser from 80°C – 95°C before going into the boiler at 150°C – 160°C. Economisers are a mature and well known technology and can save between 3% and 7% of fuel burn. There any many types of economisers. Some can be integrated into the boiler while others are external to the boiler.

Pre-heating combustion air follows the same principle as an economiser. Like economisers, air pre-heaters are a mature technology and can reduce fuel burn by 0.5% - 2%.

The use of economisers and air-pre-heaters, typically, still leaves the boiler exhaust at temperatures above 160°C. If there are applications for low temperature hot water, and providing the existing site installation allows, the boiler exhaust can be cooled to below 100°C to generate hot water at approximately 50°C to 60°C – which is useful for low-grade hot water applications and in office heating, or, if the volume allows, for district heating. Such applications are normally referred to as a condensing economiser.

Opportunities to recover heat from boiler exhaust should be maximised. In some installations, it may be physically impossible to retrofit the boiler chimney or to add an economiser, as when the boiler plant is fully surrounded by other processing plant and there is no available space to add any additional equipment. In practice, this is an exception rather than the norm.

Insulation

Any equipment that has a hotter surface than the ambient temperature will lose heat. The addition of insulation to exposed pipework and pipe fittings reduces the rate of heat loss. The use of insulation in industry is a common practice. There are many different types of insulation materials, in bespoke shapes to fit various vessels, pipe fittings such as valves, and pipe bends. Insulation can be a fixed installation or made in removable sections to allow quick access for maintenance and inspection.

Ecofys and the European Industrial Insulation Foundation (2012) estimate that the application of insulation has the potential to reduce fuel consumption in European industries by 14.8 mtoe per year. The global macro-economic benefits of insulation are difficult to estimate due to the significant number of variables involved. The energy savings that may be achieved increases with pipe or vessel surface temperature and surface area. If the installation is located outside then wind, temperature and moisture also influence the potential savings. As a guide, all surfaces above 60°C should be insulated and paybacks will be rapid.

Use energy efficient heat exchanger designs

Apart from direct-fired systems, all forms of heat are transferred from a high-temperature fluid to a lower-temperature fluid inside a heat exchanger. For example high pressure steam is used to heat low pressure fluid in a steam-to-hot-water process or a high-temperature-hot-water to lower-temperature-oil process. The most common type of heat exchanger, making up 85% of all heat exchangers, are shell and tube heat exchangers.

For low-pressure applications (typically less than 5 bar), there are more energy-efficient heat exchanger designs that have a smaller physical footprint and lower pressure drops (and are thus able to operate at a lower pumping pressure). In this category are plate heat exchangers, spiral heat exchangers and fin heat exchangers. In general, these energy-efficient heat exchangers are able to transfer more heat (95% versus 80% in shell and tube designs) and are able to operate at lower pump pressure, thus also saving electricity consumption for pumping.

At higher pressure applications and in certain applications using corrosive substances, the use of energy-efficient heat exchangers may be limited. Options to improve energy efficiency for conventional shell and tube heat exchangers are available. These include replacing the internal tube bundles with alternative designs such as twisted-tube heat exchangers, helix exchangers and expanded baffle heat exchangers. Within the same footprint, these energy-efficient bundle replacements are able to transfer up to 50% more heat at up to 50% lower pressures (See: Butterworth et al. n.d.; Shinde et al. 2012; Elstrom & Son 2011; and Oakley et al. 2007).

Where it is possible, replacing a shell and tube heat exchanger with a compact variant can save thermal energy (more heat can be transferred) and pump power (due to lower pressure loss). These energy efficient heat exchangers can be rolled out at the design stage or during plant improvement exercises.

Minimise simultaneous heating and cooling

In some industrial applications, both heating and cooling is provided to a processing unit. For example, a vessel may have heating and cooling loops. These might be operating simultaneously due to control system faults or to having the heating and cooling set points close together. Simultaneous heating and cooling is surprisingly common in industry. Identifying and eliminating these kinds of problems will save energy at little or no cost.

Return water and condensate

In industry, especially on a large site, condensate (the return water resulting from using steam for heating processes) may be passing to drains rather than being returned to the boiler plant for reuse. Steam and the resulting condensate originate from purchased water, which is treated with chemicals before going into the boiler plant. The condensate is still hot and contains usable energy. Wasting condensate wastes water, energy and chemicals and should be eliminated in well-run steam systems. Detailed analysis of the water, discussions with various water treatment specialists and a life cycle cost analysis will be necessary to fully appraise the financial benefits of returning the condensate to the boiler house and/or other alternatives.

Apart from the appropriate sized piping for condensate return, one other component is essential: the steam trap. Steam traps prevent steam from passing through but allow condensate (after the steam energy is transferred) to pass through. From an energy perspective, steam traps limit the free flow of unused steam. The correct specification of steam type and size is an essential part of maximising the energy efficiency of steam systems.

Maintenance of steam traps is essential as, on average, 10% of steam traps fail every year, in either an open or closed position. Failed closed steam traps are easy to identify as the application will not be able to achieve its operating temperature. Failed open steam traps have no observable signs and allow steam to flow through the plant and machinery. They can be detected by ultrasonic detectors or infrared cameras, carried out as part of a routine condition monitoring or steam trap survey. As a guide, all steam traps should be surveyed at least once a year and faulty traps replaced as soon as possible.

4.6.3 Cooling and refrigeration

Cooling and refrigeration are another common energy use deployed in industry. There are two principal types of cooling: air-cooled and water-cooled. Air-cooling is achieved by blowing cold air to the process that requires cooling. Water-cooling is achieved by transferring the heat from the process into water, which is later cooled by air in a cooling tower.

A refrigeration unit (commonly referred to as a chiller) has two separate circuits. One supplies chilled water to cool the process and the extracted heat is rejected by the chiller in the other circuit where it can either be air-cooled or water-cooled. There are two major chiller designs on the market: mechanical chillers, which use electricity, and absorption chillers, which utilise heat for their operation.

Conceptually, a cooling tower and refrigeration system is the reverse of a steam system. In a steam system, steam is transferring its heat into the process. In cooling applications, heat is extracted from the process. The issues and opportunities identified in the motor and driven systems and in steam systems above are applicable to cooling systems. This section identifies the additional issues and opportunities to save energy from the cooling towers and refrigeration units.

Coefficient of Performance (COP)

An important measure of efficiency for cooling and refrigeration systems (as well as heat pumps) is the Coefficient of Performance (COP) – the relationship between energy input in the form of electricity or motive power and energy output in the form of heating or cooling. The higher the COP the lower the running costs but COPs in any particular application vary widely with temperatures and duty cycles.

The COPs of a cooling tower range between 15 and 25. This means that for every 1kW of fan electricity consumed, it is able to provide 15kW to 25kW of cooling. Mechanical chillers can provide cooling with a COP ranging between 2 and 6. COPs for absorption chiller range between 0.7 and 1.1. COPs greater than 1 do not imply breaking the laws of thermodynamics but are possible because the heat pump is taking heat from another source such as ambient air or water.

Ensure good access to cooling air

Heat rejection from cooling systems is usually to ambient air and good access to ambient air is necessary to allow for efficient heat rejection. Sometimes siting restrictions and bad engineering practices result in badly sited units with restricted air flow or cooling air intakes being positioned next to hot air exhausts which results in lower than ideal efficiency. As a rule of thumb, every 1°C rise in the cooling air temperature causes a 3% power increase by the chiller. All cooling towers and chillers should have good access to the coolest possible air.

4.6.4 Water chemistry

Water is a useful medium for carrying and transferring heat, either directly or as steam. However, water contains other elements such as mineral salts (sodium salts, magnesium salts, etc.), dissolved gases (such as oxygen, carbon dioxide, etc.), dissolved organic matter, and microbiological organisms. These elements, present in trace quantities, can significantly affect the properties of water and directly impact on energy efficiency and maintenance of plant and equipment through the following mechanisms:

- mineral salts at high temperature can cause scaling, which reduces heat transfer by forming an insulating layer on heat transfer surfaces within heat exchangers.
- dissolved gases at low temperatures are the reason why heat exchangers with cooling or refrigeration duties tend to suffer from corrosion problems.
- undissolved solids in water, under certain conditions, can carry over into the pipes and process plants to cause erosion.
- microbiological organisms, under the right conditions, may proliferate in the water system.

For these reasons, improving the quality of feed water into a boiler or cooling tower can save money through:

- reducing water purchase
- reducing water treatment
- protecting plant from corrosion and erosion
- reducing energy consumption from pre-heating or pre-cooling the water to operating temperatures
- reducing trade effluent.

In cooling tower and chilled water systems further savings can occur through a reduction in heat exchanger scaling, and therefore a reduction in heat exchanger cleaning time and/or an increase in production availability. Due to the potential or multiple benefits when improving water quality, it is advisable to work closely with specialised water treatment companies to identify all potential benefits for the site and to assess the opportunity based on a life cycle cost analysis.

4.6.5 Buildings

Industrial enterprises tend to focus their efforts on energy intensive processes. Compared to the process, the buildings they occupy tend to be lower priority in terms of design, commissioning, operations and maintenance, which is not surprising as the energy costs of buildings are only a small proportion of total energy costs. Despite this there may be quick wins for energy savings in industrial enterprises in the buildings they occupy. Making these improvements can also be a useful means to build awareness, and involve employees in energy savings. Three common areas where energy savings can be found in buildings are: the building fabric, the Heating, Ventilating and Air Conditioning (HVAC) systems and lighting.

One of the most effective means of limiting heat loss (or gain) is via the improvement of building fabric. Should the industrial site choose to erect a new building, energy efficient features can be incorporated at the design stage. Simple solutions are also available for existing buildings:

- For windows: window frames can be tested to ensure that they can be closed tightly and draught-proofing applied. Single glazed windows can be replaced with double- or triple-glazed variants. Shading can prevent over-heating.
- For doors: door frames can be tested to ensure they can be closed tightly and draught-proofing applied. Thicker doors and self-closing mechanisms can be deployed.
- For roofs and walls: gaps can be closed, and additional insulation be applied. In hot climates, insulation can keep unwanted heat out.

Well-controlled HVAC systems are another effective way to save energy in all climates. The aim should be to maximise comfort and health by controlling humidity, temperature and air quality with the minimum input of energy.

Lighting is another simple way to save energy. There are many combinations of energy saving techniques and technologies for lighting. In general, lighting energy savings arise in three ways:

- Not all areas of a building are occupied all of the time. Automatic controls and sensors can be deployed to match lighting provision to need.
- Reducing the lighting levels where there is over lamping. There are standard recommendations for lighting levels according to purpose. Meeting these can reduce electricity consumption.
- Implementing more energy-efficient Light Emitting Diode (LED) lighting will save electricity.

LED sales are rapidly growing in all markets and becoming the dominant lighting technology. Lasting for an average of 40,000 hours, compared to incandescent bulbs' 1,000 hours, LEDs have an extended working life, significantly reduce CO_2 emissions, reduce power bills by 50 to 90% and minimise replacement (i.e. maintenance) costs. Modern designs slot into existing fixtures and fittings and designers are producing ever more versatile lighting possibilities. The US Department of Energy has calculated that using LEDs in industry could save 88 TWh (terawatt-hours) of electricity in the US between 2010 and 2030 – enough to power 7 million homes for a year (US DOE 2011). Replacing incandescent, halogen and high-intensity discharge (HID) lighting with LED equivalents can also reduce cooling loads on air conditioning, adding to the energy saving benefits. Lighting retrofits are relatively easy and quick to implement and LED costs are falling all the time.

4.6.6 Combined heat and power

Conventional power generation technologies such as gas turbines, depending on their capacity, have low fuel-to-power efficiencies. For reciprocating engines, energy efficiency ranges between 28% and 38%. For gas turbines up to 5MW, energy efficiencies are in the range of 20% to 25%. From 5 MW to 500 MW, efficiency ranges between 25% and 35%. Above 500 MW efficiencies of up to 50% can be achieved from new plant. These low efficiencies are because much high-temperature heat is lost through the stack.

Combined heat and power (CHP or cogeneration) captures and utilises this energy. In large power stations it can be used to generate steam which is put through a steam turbine to generate more electricity. This application of gas turbine and steam turbine plants is frequently referred to as combined cycle gas turbine (CCGT). At the smaller scale CHP can use industrial gas turbines (from 2 MWe output) or reciprocating engines (between 100kW and 2 MW) burning gas or oil. The recovered heat can be used to generate steam, hot water or a combination of both (depending on the fuel). This capture of power and heat is frequently referred to as co-generation. Typically, the combined efficiency of such plants is much higher: 75% – 85%.

CHP is an attractive option for many industrial sectors, particularly when both electricity and heat is required in a process with high operating hours. The IEA (2007) estimates the utilisation of CHP plants in industry could save between 48 to 72 mtoe annually. For sites that have demand for electricity, heat and chilled water, the heat from a co-generation plant can be utilised in absorption chillers to generate chilled water. The generation of power, heat and chilled water is known as tri-generation. It is used in the food manufacturing, electronic and pharmaceutical industries.

The detailed sizing of a CHP plant involves understanding the electricity consumption, heat consumption and chilled water consumption profiles. Good designers will weigh the different design options, sizing, and recommend one that gives the lowest operating costs.

Although more unusual, it is also possible to convert the CO_2 from the CHP exhaust into usable forms, for use in greenhouses, CO_2 fire extinguishers, and in bottling carbonated drinks. The combination of power, heat, chilled water, and CO_2 production is sometimes known as quad-generation.

CHP is a proven technology and the opportunity to deploy CHP should be explored and exploited in industry. When considering CHP investments, one reason for not pursuing the opportunity is the lack of electricity demand or a lack of heat demand within the organization. By applying "out of the boundary" thinking and connecting to local power grid and heat networks, it is possible to sell heat or power in a local energy hub, producing additional revenue for the investor. This has been demonstrated in many district heating and cooling systems around the world.

4.6.7 Heat recovery

It is estimated that 20-50% of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, or heat loss from equipment surfaces and heated items. Any industrial process which uses heat can reduce energy use either by using heat exchangers to transfer the heat somewhere else to where it is useful in another process, or, if the temperature is sufficiently high, to generate electricity. The most common use of recovered heat is to preheat inputs to furnaces. Heat may either be reused within the same or a different process, or sometimes by a neighbouring industrial facility. The temperature of the heat determines its possible use. While steel, aluminium and cement processes require very high temperatures (around 1,450°C for clinker production), paper production only needs heat at around 150 – 200°C to evaporate water from wet pulp, while plastics manufacture at 200°C.

Numerous technologies are commercially available for waste heat recovery, yet in many applications it remains relatively unexploited. For it to be successful, an accessible source of waste heat, the correct recovery technology, and a use for the recovered energy need to be present. Facilities may need specialist help in identifying these and in evaluating the feasibility of waste heat recovery.

Heat-cascading systems, where waste heat from one company is used by another, are a promising option for saving energy. In parts of Sweden waste industrial heat is used to provide heat into district heating which heats nearby houses. Elsewhere it is used to heat greenhouses which may grow crops such as tomatoes. Greater integration of heat sources and heat demand through heat recovery is a valuable opportunity.

4.6.8 Waste heat to power

In some industrial processes, such as steel and cement industries, temperatures above 1,000°C are used in the production process and the waste heat from the process can be as high as 750°C. In CHP plants and boiler plants, the waste heat can be as high as 160°C to 180°C. Depending on the temperature of the exhaust, various technologies can be used to convert waste heat to power – an approach sometimes called Waste Heat to Power (WHP). At high temperatures steam can be generated and used in steam turbines. This technology has been widely used in China, where over 700 installations have occurred in the cement industry alone (Hook 2013). At lower temperatures the waste heat can also be recovered to generate electricity using a technology called Organic Rankine Cycle (ORC). This is similar to a steam turbine but uses organic fluids with a boiling point lower than water and it is well proven around the world. Industrial sites with high temperature waste heat should investigate waste heat to power options.

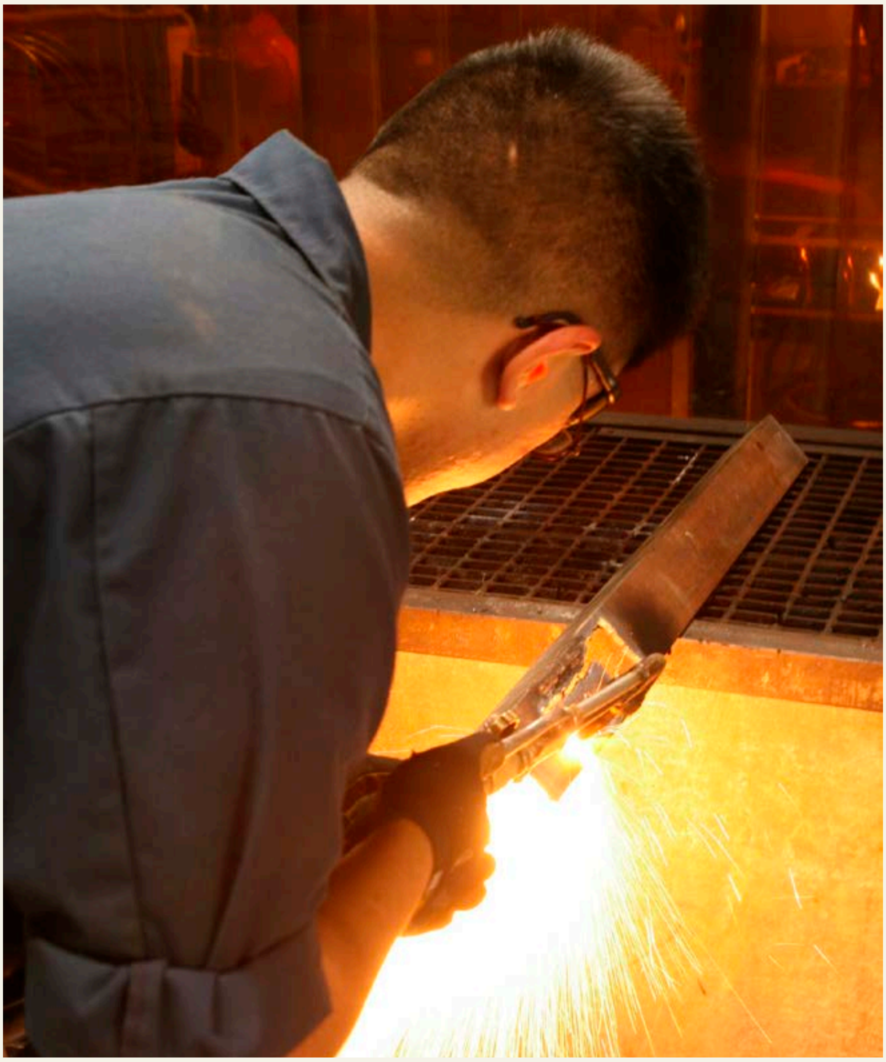


Photo: Cpl. Jacob A. Singsank

4.6.9 Energy from waste

Waste materials which cannot be reused and recycled, and which have an energy content, can be used as an energy source. This is commonly achieved via incineration with energy recovery (CHP). Anything that can burn in a controlled environment is a good candidate. Increasingly, depending on the feedstock, non-incineration options are available such as gasification, anaerobic digestion and fermentation to generate liquid fuel. IEA (2007) estimates that these technologies have an energy saving potential of 36 - 55 mtoe annually.

The cement industry has widely exploited opportunities to burn waste streams. In Poland, for instance, nearly all cement plants have received permits from their local regulators to process Residue Derived Fuel (RDF) or Solid Recovered Fuel (SRF). The waste derived fuels substitute for coal. It is estimated that worldwide the cement industry is burning 100 million tonnes of waste derived fuels a year but that this reflects only 20% of the potential (Theulen 2015).

4.7 Shortlist of energy efficiency opportunities in key industrial sectors

As well as the cross-sectoral, non-process opportunities identified above, all categories of industrial processes have opportunities to improve their energy efficiency. It is impossible to describe all of these but many sources of information on the technologies of energy efficiency are available. One such source is the Lawrence Berkeley National Laboratory (LBNL), which conducts research in collaboration with governments and industry into the more effective and productive use of energy, both in the US and globally. LBNL has developed sector-specific energy efficiency technology guidebooks that help assess energy-saving opportunities. Summaries of the major opportunities by sector are presented below.

4.7.1 Chemicals and petrochemical

A shortlist of chemical and petrochemical industry-specific energy efficiency opportunities is presented in Table 6.

Table 6. Shortlist of sector specific energy efficiency opportunities – chemicals and petrochemicals
Source: Adapted from Neelis et al., 2008

Sub-Sector/Product	Energy efficiency opportunities	
Ethylene	• More selective furnace coils • Improved transfer line exchangers • Secondary transfer line exchangers • Increased efficiency cracking furnaces • Pre-coupled gas turbine to cracker furnace • Higher gasoline fractionator bottom temperature • Improved heat recovery quench water	• Reduced pressure drop in compressor inter-stages • Additional expander on de-methanizer • Additional re-boilers (cold recuperation) • Extended heat exchanger surface area • Optimisation of steam and power balance • Improved compressors
Aromatics	• Improved product recovery	
Polymers	• Low pressure steam recovery • Gear pump to replace extruder • Online compounding extrusion • Re-use solvents, oils and catalyst	
Ethylene oxide / ethylene glycol	• Increased selectivity catalyst • Optimal design EO/EG-sections • Multi-effect evaporators	• Recovery and sales of by products • Process integration
Ethylene dichloride / Vinyl Chloride Monomer	• Optimise recycle loops • Gas-phase direct chlorination of ethylene • Catalytic cracking EDC	
Styrene	• Condensate recovery and process integration	
Iron ore and ferrous reverts Iron ore and preparation (Sintering)	• Heat recovery from sintering and sinter cooler • Reduction of air leakage • Increasing bed depth	• Emissions optimised sintering • Use waste fuel in sinter plant improved charging method • Improve ignition oven efficiency

4.7.2 Iron and steel

The iron and steel industry is the largest energy consumer of all the industrial sectors, and energy costs as a proportion of total costs are high – up to 40% in steel making (Deloitte 2008). Available processes to improve energy efficiency include enhancing continuous production processes to reduce heat loss, increasing recovery of waste energy and process gases, and efficient design of electric arc furnaces, for example scrap pre-heating, high-capacity furnaces, foamy slagging and fuel and oxygen injection. A further refinement is 'near-net-shape casting', which produces items close to their final shape rather than standard ingots which then have to be rolled and pressed, thus eliminating very energy-intensive processes that use large amounts of heat and electricity.

A shortlist of iron and steel industry-specific energy efficiency opportunities is presented in Table 7.

Table 7. Shortlist of sector specific energy efficiency opportunities – iron and steel
Source: Adapted from Worrell et al., 2010

Sub-Sector/Product	Energy efficiency opportunities	
Iron making – blast furnace	• Injection of pulverised coal • Injection of natural gas • Injection of oil • Injection of plastic waste • Injection of coke oven gas and basic oxygen furnace gas • Charging carbon composite agglomerates • Top pressure recovery turbines	• Recovery of blast furnace gas • Top gas recycling • Improved blast furnace control • Slag heat recovery • Pre-heating of fuel for hot stove • Improvement of combustion in hot stove • Improved hot stove control
Steelmaking – Basic oxide furnace	• Recovery of BOF gas and sensible heat • Variable speed drive on ventilation fans • Ladle pre-heating	• Improvement of process monitoring and control • Efficient ladle heating programme
Steelmaking – EAF	• Variable speed drives • Oxy-fuel burners / lancing • Post combustion of flue gasses • Improving process control • Direct current are furnace	• Scrap pre-heating • Waste injection • Air tight operation • Bottom stirring / gas injection
Casting and refining	• Integration of casting and rolling • Lade pre-heating • Tundish heating	
Metal shaping	• Use efficient drive units • Gate communicated turn off inverters • Installation of automated lubrication system	
Hot rolling	• Recuperative or regenerative burners • Flameless burners • Controlling oxygen levels • Variable speed drives on combustion air fans • Hot charging	• Integration of casting and rolling • Proper reheating temperature • Process control in hot strip mill • Heat recovery to the product • Waste heat recovery from cooling water
Cold rolling	• Continuous annealing • Reducing losses on annealing line	• Reduced steam use in the acid pickling line • Inter-electrode insulation in electrolytic pickling line

4.7.3 Cement

The production of cement is very energy and carbon intensive. The IEA (2007) estimates that the global cement industry could save between 28 and 33% of total energy use by the adoption of best practice commercial technologies.

A shortlist of cement industry-specific energy efficiency opportunities is presented in Table 8.

Table 8. Shortlist of sector specific energy efficiency opportunities – cement industry
Source: Adapted from Worrell and Galitsky, 2008

Sector	Energy efficiency opportunities	
Cement production – raw materials preparation	• Efficient transport systems (dry process) • Slurry blending and homogenisation (wet process) • Raw meal blending systems (dry process) • Conversion to closed circuit wash mill (wet process)	• High-efficiency roller mills (dry process) • High-efficiency classifiers (dry process) • Fuel Preparation: Roller mills
Clinker production (wet)	• Energy management and process control • Seal replacement • Kiln combustion system improvements • Kiln shell heat loss reduction • Use of waste fuels • Conversion to modern grate cooler • Refractories	• Optimize grate coolers • Conversion to pre-heater, pre-calciner kilns • Conversion to semi-dry kiln (slurry drier) • Conversion to semi-wet kiln • Efficient kiln drives • Oxygen enrichment
Clinker production (dry)	• Energy management and process control • Seal replacement • Kiln combustion system improvements • Kiln shell heat loss reduction • Use of waste fuels • Conversion to modern grate cooler • Refractories • Heat recovery for power generation • Low pressure drop cyclones for suspension	• pre-heaters • Optimise grate coolers • Addition of pre-calciner to pre-heater kiln • Long dry kiln conversion to multi-stage • pre-heater kiln • Long dry kiln conversion to multi-stage • pre-heater, pre-calciner kiln • Efficient kiln drives • Oxygen enrichment
Cement production – finish grinding	• Energy management and process control • Improved grinding media (ball mills) • High-pressure roller press • High efficiency classifiers • General Measures • Preventative maintenance (insulation, compressed air system, maintenance) • High efficiency motors • Efficient fans with variable speed drives	• Optimisation of compressed air systems • Efficient lighting • Product & Feedstock Changes • Blended Cements • Limestone cement • Low Alkali cement • Use of steel slag in kiln • Reducing fineness of cement for selected uses

4.7.4 Paper and pulp

With pulp and paper production, opportunities to improve energy efficiency include: cogeneration, increased use of (self-generated) biomass fuel, and increased recycling of recovered paper, efficient motors and improved efficiency of steam use. Energy consumption by the pulp and paper industry could be reduced by 15 - 18% by adopting best practice commercial technologies.

A shortlist of pulp and paper industry-specific energy efficiency opportunities is presented in Table 9.

Table 9. Shortlist of sector specific energy efficiency opportunities – pulp and paper
Source: Adapted from Kramer et al., 2009

Sector	Energy efficiency opportunities	
Pulp and paper – raw material preparation	• Cradle debarkers • Automatic chip handling and screening • Replace pneumatic chip conveyors with belt conveyors	• Bar-type chip screening • Use secondary heat instead of steam in debarking • Chip conditioning
Chemical pulping – pulping	• Use of pulping aids to increase yield • Digester blow/flash heat recovery • Optimise the dilution factor control • Heat recovery from bleach plant effluents	• Continuous digester control system • Improved brownstock washing • Digester improvement • Chlorine dioxide heat exchange
Chemical pulping – bleaching	• Heat recovery from bleach plant effluents • Chlorine dioxide heat exchange • Improved brownstock washing	
Chemical pulping – chemical recovery	• Lime kiln oxygen enrichment • Improved composite tubes for recovery boiler • Lime kiln modification • Recovery boiler deposition monitoring	• Lime kiln electrostatic precipitation • Quaternary air injection • Black liquor solids concentration
Mechanical pulping	• Refiner improvements • Increased use of recycle pulp • Refiner optimisation for overall energy use • Heat recovery from de-inking plant • Pressurised groundwood • Fractionation of recycled fibers	• Continuous repulping • Thermopulping • Efficient repulping rotors • Drum pulpers • Heat recovery in thermomechanical pulp
Paper making	• Advanced dryer controls • Waste heat recovery • Control of dew point • Vacuum nip press • Energy efficient dewatering – rewetting • Shoe (extended nip) press	• Dryers bars and stationary siphons • Reduction of blow through losses • Belt drying • Reduction air requirements • Air impingement drying • Optimising pocket ventilation temperature

4.7.5 Vehicle assembly

A shortlist of vehicle assembly-specific energy efficiency opportunities is presented in Table 10.

Table 10. Shortlist of sector specific energy efficiency opportunities – vehicle assembly
Source: Adapted from Galitsky et al., 2008

Sector	Energy efficiency opportunities	
Vehicle assembly – painting	• Minimise stabilisation periods • Reduce air flow in pain booths • Utilise heat recovery • Efficient ventilation system • Efficient oven type • Infrared paint curing • UV paint curing • Microwave heating	• Wet on wet paint • New paint – powders • New paint – powder slurry coats • Ultrafiltration / reverse osmosis for waste water cleaning • Carbon filters and other volatile carbon organic removers • High pressure water jet system
Vehicle assembly – body weld	• Computer control • High efficiency welding / inverter technology • Multi-welding units	• Frequency modulated DC welding machine • Hydroforming • Electric robots
Vehicle assembly – stamping	• Variable voltage controls • Air actuators	

4.7.6 Pharmaceutical

A shortlist of pharmaceutical-specific energy efficiency opportunities is presented in Table 11.

Table 11. Shortlist of sector specific energy efficiency opportunities – pharmaceuticals
Source: Adapted from Galitsky et al., 2008

Sector	Energy efficiency opportunities	
Pharmaceutical – R&D	• Fume cupboard controls • Variable speed driven fans • Energy efficient clean rooms	
Pharmaceutical – Primary manufacturing	• Close-system sterilisation • Variable flow control for process air • Energy efficient agitation	
Pharmaceutical – Secondary manufacturing	• Variable speed driven fans • Variable speed driven vacuum • Multiple effect evaporation	• Optimise the operation of pharmaceutical water generation • Recover and reuse water from water treat-ment plant for other applications

4.7.7 Glass industry

A shortlist of glass-specific energy efficiency opportunities is presented in Table 12.

Table 12. Shortlist of sector specific energy efficiency opportunities – glass industry
Source: Adapted from Worrell et al., 2008

Sector	Energy efficiency opportunities	
Glass – Batch preparation	• Grinding – new technology • High-efficiency motors • Mixing variable speed drives • Fluxing agents • High efficiency belts • Reduce batch wetting	• Conveyor belt systems • Selective batching • Cullet separation and grinding systems • Optimise conveyor belts • Cullet preparation
Glass – Melting task	• Process control systems • Refractories/Insulation • Minimise excess air/reduce air leakage • Properly position burners • Premix burners • Sealed burners • Variable speed drives on combustion air fans	• Low-NOx burner • Waste heat boiler • Recuperative burners • Bubbler • Vertically-fired furnaces • End-fired furnaces • Regenerative furnaces
Glass – Melting task – Oxy-fuel furnace	• Synthetic air • Heat recovery from oxy-fuel furnace • Oxygen enriched air staging	• High luminosity burners (oxy-fuel) • Oxy-fuel furnace • Tall crown furnace (oxy-fuel)
Glass – Melting task – Electric furnace	• Top-heating • Replace by fuel-fired furnace • Optimise electrode placement	
Glass – Melting task – Cullet use and pre-heating	• Use more cullet and or filter dust • Batch and cullet preheating	
Glass – Forehearths and forming	• Process control • Oxy-Fuel fired forehearth	• High efficiency forehearths • Improved insulation
Glass – Annealing and finishing	• Improve process controls • Improved insulation • Optimise plant lay-out	• Product drying system upgrade • Reduce air leakage • Glass coating

4.8 Conclusions

The techniques of energy management are well known and have been effectively applied to enterprises across all sectors. Implementing the basic principles of energy management will improve energy efficiency. This means the application of monitoring and targeting and moving through the energy management maturity model from good housekeeping through to investment in simple modifications, and then process integration. Now that best practices in energy management have been codified into the international standard ISO 50001 there is a standardised approach that can be disseminated throughout industry to increase skill levels. ISO 50001 and capacity building are discussed in Chapter 7. Spreading the implementation of sound energy management and improving the quality of energy management should be the foundation of any policy to improve industrial energy efficiency.

The technologies for improving energy efficiency across all industries are mature and well proven. Improving energy efficiency does not require developing new technology – simply adopting the best available, and well proven, technologies would significantly improve industrial energy efficiency levels in all countries. Policies should be focused on accelerating the adoption of mature, well proven and economic energy efficiency measures. Across all industries there is a wide spread of energy performance i.e. energy per unit of output, (often a ratio of 2:1 between worst and best performance). Just by reducing this spread of performance, significant gains in energy efficiency will result.

Key points:

- Energy management is a well proven discipline that works across all industrial sectors.
- Energy management systems should first focus on good housekeeping before moving onto more complex retrofits and process integration.
- ISO 50001 is the international standard for energy management and its use should be encouraged by policy makers.
- Measurement and Verification (M&V) is a key component of any energy management system.
- Sector specific and cross-sectoral technologies for energy efficiency are mature and well proven.
- Electric motors account for 60% of industrial electricity use globally and therefore are a key priority.
- There is a wide spread of energy performance within all industry sectors and just reducing this spread will result in significant energy savings.

CHAPTER 5.

Barriers to Improving Energy Efficiency in Industry

"Removing barriers to energy efficiency is a lot smarter and cheaper than trying to get millions of individuals over these barriers".

– Stefan Scheuer, Secretary General of the Coalition for Energy Savings

5.1 Introduction

The large potential for improved energy efficiency, and the benefits it brings to companies and national economies, is not matched by the level of adoption. This "energy efficiency gap" is observed in all economies. The primary role of policy should be to maximise the take-up of economic opportunities and reduce this energy efficiency gap. This chapter examines the barriers that exist to doing so, both at government level and within enterprises.

5.2 Government and policy barriers

Several of the existing barriers to improving energy efficiency are directly under the control of governments.

5.2.1 Bias towards energy supply side

Two of the important barriers in government are a lack of appreciation of the value of energy efficiency in improving productivity and the economy and a fundamental bias amongst energy professionals and policy makers towards energy supply options. One way in which this manifests itself is when formulating infrastructure plans (generation and networks) for meeting future energy demand. Energy planners regularly overestimate future energy demand and do not include the potential of energy efficiency as a resource to meet future demand. Policy makers need to guard against this inherent bias and seek out better models of future energy demand that more accurately reflect the impact of enhanced energy efficiency. Energy efficiency should be considered as a clean, low cost and easily accessible, resource to be included in energy planning. The full range of multiple benefits also needs to be understood and evaluated.

Properly valuing all of the benefits of improved energy efficiency should lead to it being given a high priority, above the extension of the energy supply capacity where this can be shown to be cost-effective, as is often the case.

5.2.2 Lack of data

One of the challenges that energy efficiency presents to policy makers is that its effect is the sum of many thousands of decisions taken across the economy. Therefore it is hard to collect data on what is actually happening within enterprises. Policy makers seeking to improve industrial energy efficiency must determine what data sources are already available and can be used, perhaps making use of proxies for key data that is unavailable, and put in place other appropriate data collection mechanisms.

The overall objectives of industrial energy efficiency policy are to improve energy intensity (energy per GDP) for the whole economy and the energy productivity of industrial enterprises. A hierarchy of indicators which require information flows can be established. This starts with overall industrial energy use per GDP and moves down into energy per output for each sector, and even each enterprise. Enterprise-level information can often be collected by trade associations. They can provide benchmarking services of sector-wide data to individual enterprises. A good example of this is the UK's brewing industry.

The UK brewing industry

In 1976 the trade association (then called the Brewers' Society now called the British Beer and Pubs Association) responded to a call from the then UK Department of Energy (now DECC) to set a target for improving the energy productivity of their member breweries. Standardised data normalised for brewery size, production levels and product type has been collected every two years since then. It provides both a useful illustration of an industry continuously improving its energy efficiency as well as the basis of a voluntary agreement with government (BBPA 2006).

Between 1976 and 2006 the specific energy consumption of the UK brewing industry fell by 54%. Since then the industry has continued to make improvements in energy efficiency (BBPA 2014).

5.2.3 Energy prices and subsidies

In many countries energy prices have been subsidised for social and economic reasons. However, low energy prices reduce the incentives for consumers and industry to invest in more energy-efficient appliances and equipment. In 2009 the G20 countries agreed to phase out fossil fuel subsidies. Although dismantling subsidies can be very difficult, it is vital that countries implementing energy efficiency measures are aware of this conflict of interest and the mixed signals generated. Guidance on reforming subsidies is provided by the Global Subsidies Initiative (GSI & IISD 2013).

There are various definitions of subsidies for fossil fuels. The IEA considers only the difference between a reference (market) price and the end-user price. On this basis the IEA (2013) estimated subsidies in 2013 were worth USD 548 billion for fossil fuels, 4.5 times higher than the USD 121 billion subsidies for renewable energy.

In a more recent study the International Monetary Fund (IMF) has estimated dramatically higher subsidies for fossil fuels: USD 5.3 trillion, or 6.5% of global GDP in 2015 (IMF 2015).

The IMF says that "most of this arises from countries setting energy taxes below levels that fully reflect the environmental damage associated with energy consumption". These numbers are much higher than the IEA's because they include a value for environmental damage and damage to health.

Although reforming energy prices is an essential part of improving energy efficiency, even at low energy prices there is usually potential to improve industrial energy efficiency significantly, and active energy efficiency programmes can be implemented even in jurisdictions with low energy prices. Abu Dhabi is an example of this, where the non-economic benefits of energy efficiency are stressed at the highest level.

Energy efficiency in Abu Dhabi

Energy efficiency in Abu Dhabi, in particular Abu Dhabi Company for Onshore Oil Operations (ADCO), is a good example of having an active energy efficiency programme even when energy prices are low. As an oil producing nation, energy sources are in abundance and available cheaply in Abu Dhabi. If ADCO were to justify energy savings based on cost savings, it would not have any paybacks (Zamzam 2013). Energy saving projects are justified because the leader of the Nation, H.H. Sheik Zayed bin Sultan Al Nahyan says it is a good thing:

"*On land and in the sea, our forefathers lived and survived in this environment. They were able to do so only because they recognised the need to conserve it, to take from it only what they needed to live, and to preserve it for succeeding generations.*"

The spirit of conservation and preservation is captured in ADCOs vision, missions, and policy. ADCO has a mission to operate their plants at "*maximum efficiency, optimum cost with minimum impact to the environment and minimum harm to people*". They believe this is in line with meeting their shareholders' aspiration. They are committed to the use of best available technology and practices to progressively reduce emissions, discharges and waste, improve the efficient use of energy and conserve natural resources. Collectively, these become the yardsticks where ADCO is measuring their performance – and the justifications for energy saving projects (Zamzam 2014).

5.2.4 Utility regulation and tariffs

The nature of utility regulation in a country can impact directly on industrial energy efficiency. One positive way is that utilities can be mandated to spend money on improving the efficiency of their customers or providing assistance to customers.

But some utility regulations have the opposite effect. In many markets utilities are rewarded according to their capital expenditure (earning a set rate of return on eligible energy supply investment), giving no incentive for a utility to consider investment in energy efficiency compared to investment in increasing supply through new generation plant or increased supply capacity. Tariff structures where lower rates are offered for greater consumption can also negatively affect energy efficiency. Another discouragement for energy efficiency happens where regulations prevent or make more expensive the connection of local generation technologies such as CHP.

A comprehensive energy efficiency policy should tackle these issues and consider the interactions between energy supply regulation and the aim of improving industrial energy efficiency.

5.3 Barriers within enterprises

The barriers to improving energy efficiency within enterprises have been researched over many years. In the early years, these barriers were thought of as being predominantly economic. Subsequently, it was realised that they include regulations, incentives, technical issues, factors within managerial decision-making, financial, behavioural, and sub-categories of the above.

The first systematic attempt to classify these barriers was carried out by Blumstein in 1980. This work has been adapted and modified over time by researchers, enterprises, governments and NGOs. Foremost amongst these are the Intergovernmental Panel on Climate Change (IPCC 2001), Weber (1997) and Sorrell et al. (2000), whose work has been revised and modified and used by UNIDO. The six major barriers at the organizational level are shown in Table 13.

It should be noted that there is still a lack of statistically significant data on the types of barriers and their quantitative effects from research within industry and within governments.

Table 13. Barriers to energy efficiency taxonomy
Source: Adapted from Sorrell et al., 2011

Barrier category	Brief description
Perceived risks	Short paybacks required. Business and market uncertainty.
Imperfect information	Insufficient information on energy efficiency opportunities to assess business risks. Non-energy benefits were not quantified.
Hidden costs	Energy efficiency opportunities were not fully designed prior to capital sanction. Energy efficiency opportunities had knock-on effects that were not assessed.
Access to capital	Insufficient capital for investment.
Split incentives	Energy efficiency opportunities are foregone the cost and benefits are misaligned.
Bounded rationality	Other business priorities led to energy efficiency opportunity being side lined.

5.3.1 A business viewpoint on barriers to energy savings

Although the academic and economics-based work on barriers can be useful as a framework, it is important to consider how decisions about energy efficiency get made within enterprises. An Economist Intelligence Unit survey of 317 manufacturing companies found that they had only invested in low-risk low-saving energy efficiency opportunities in the previous three years (EIU 2013). It revealed that nearly 80% of their capital investment had been in the buildings occupied. This implies that they missed opportunities within their process plant.

Another survey, by Accenture and the UN Global Compact (2013), found 67% of CEOs, from 27 industrial sectors across 103 countries, acknowledged that they are not doing enough to address global sustainability issues. The Harvard Business Review (2013), the Economist Intelligence Unit (Coca Cola 2013) and Financial Times (Coca Cola 2014) have surveyed executives of large enterprises across the globe. The findings from these sources are not usually reported in the energy management and energy efficiency sectors, but only to business and management personnel. Figure 5 shows the top ten barriers that the Harvard Business Review found to be hindering progress. Of these, seven were internal issues within the influence of top management and controllable by the organization itself. These seven were:

- failure to assess the side effects and/or consequence of doing nothing
- uncertainty over the viability of proposed energy savings projects
- leadership attitudes towards avoiding new costs
- insufficient collaboration among stakeholders in the company
- corporate culture resistant to new ideas for improvement
- financial constraints such as high return in investment required
- poor innovation by existing suppliers and business partners.

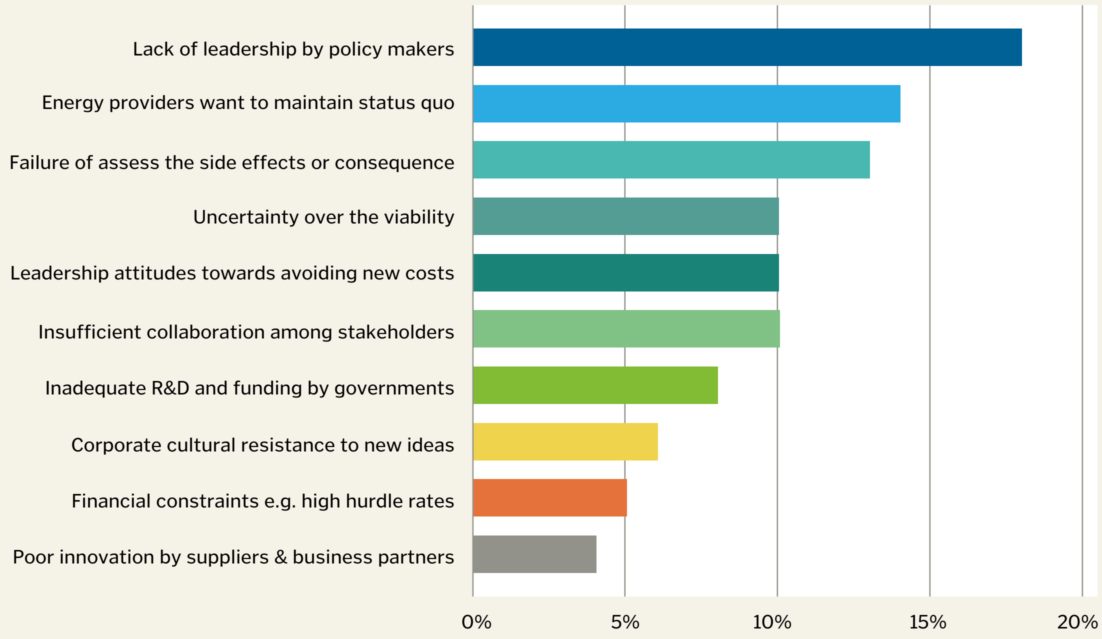
Three reasons were external to the organization:

- energy suppliers wanting to maintain status quo
- the number and complexity of regulations
- lack of government funding.

The study by The Economist and The Financial Times shows similar findings. Barriers can be divided into those that are internal to the enterprises that could improve efficiency, which need to be understood and taken into account by policy makers, and those that are external to the enterprises such as utility regulation and energy pricing. In summary, they are:

- quick returns required from energy efficiency
- uncertainty over the actual outcomes from energy efficiency
- failure to assess the risk of doing nothing or too little compared to competitors
- cost saving is deemed a lower priority than capital spending to increase business capacity.

Figure 5. Harvard Business Review Analytical Service barrier findings.
Source: Adapted from Harvard Business Review, 2013



5.3.2 Understanding decision making within enterprises

As already mentioned, one barrier to energy efficiency investment is short payback requirements from senior management. Referring back to the survey by McKinsey & Company (2015) where 10% to 20% of the energy savings can come from operational improvements, many of the opportunities have a quick return between two and three years, with a majority of commercially-available opportunities paid back within five years. IBM, the global computing giant, has been implementing energy savings since 1974 and can still find energy saving opportunities with a two-year payback (Henderson et al. 2009).

One significant study on energy management within enterprises that has shed considerable light on the discussion of barriers to energy efficiency is Cooreman's (2007) work on the "Strategic fit of energy efficiency". Cooremans examined the investment decision-making processes within enterprises and concluded that:

- investment decisions are affected by the characteristics of the proposed investment, factors internal to the organization such as financial performance and culture, factors external to the organization such as regulation, and the individual actors involved.

- the strategic logic of an investment is more important than the financial logic (i.e. the more strategic an investment is considered the more likely it is to go ahead). Strategic investments contribute to building, maintaining or improving competitive advantage which has three dimensions:
  - adding value to customers
  - the cost of producing that value
  - risks.

- energy efficiency investments are:
  - not generally considered strategic
  - are perceived as low risk
  - have a low stimulus for action
  - championed by lower level staff.

Cooremans discovered that:

- the fact that energy-efficiency investments are often not perceived as strategic by the organizations is the main reason explaining negative decisions
- the cultural dimension of energy use partially explains why these investments are not perceived as strategic
- the level within the organization at which energy management occurs is an important driver of investments decisions in energy efficiency.

But what drives which decisions get made? Cooreman's (2012) follow-up research identified that there are four aspects to the process:

- profitability plays an important but not decisive role in investment decision making
- the diagnostic phase is crucial
- there is competition between investment projects
- investment projects which are considered as more strategic win the competition.

"Thus, strategic character appears as being more important than profitability" she concludes. Therefore: "the way a project is categorised influences the procedure and the profitability assessment method".

This approach leads Cooremans to propose a different way of considering barriers to energy efficiency investments, as follows:

- Base barriers – such as lack of information. If decision makers do not know that an energy efficiency option exists it will not be invested in.
- Symptom barriers – such as the hidden costs, access to capital, risk (or perceived risk).
- Real barriers – such as a lack of strategic imperative to invest in energy efficiency measures.
- Hidden barriers – such as cultural factors within the organization.

Cooreman's work is useful for understanding the decision making process within enterprises and the barriers to adopting energy efficiency technologies. This understanding should be used in the design of more effective policies.

5.3.3 Investment related barriers

As well as the managerial barriers identified above there are also barriers associated directly with investing in energy efficiency. These include:

- the fact that energy efficiency investments are usually small compared to plant replacement or energy supply options
- they produce savings which can be hard to measure compared to revenue streams
- they are often not standardised with different vendors and project developers calculating savings and presenting projects in very different ways.

These barriers are important irrespective of the source of capital but can be particularly relevant to third party investment. This is explored further in Chapter 9.

5.4 Conclusions

Policy makers need to fully understand the barriers that hinder investment in cost-effective energy efficiency in their industrial sector. They must design and implement policies and programmes that help enterprises overcome the barriers. They must tackle both barriers that are within enterprises and industries, and those that are external to enterprises and directly under their control. These include energy prices and utility tariff structures. Various policy levers are available. These are discussed in the next chapter along with the overall principles of effective policy making.

Key points:

- Barriers to improving industrial energy efficiency are well understood.
- The barriers are split into external to the enterprise (relating to wider government policy) and internal to the enterprise (resulting from managerial factors).
- External barriers include: supply side bias amongst policy makers, subsidised energy prices and utility regulation.
- Internal barriers within firms include: lack of knowledge, lack of finance and the improved efficiency not being regarded as strategic.
- Policy makers need to understand the nature of barriers within industrial enterprises in order to design more effective policies.

CHAPTER 6.

Establishing Policy and Basic PolicyLevers

"Policy making is the process by which governments translate their political vision into programmes and actions to deliver 'outcomes', desired changes in the real world."

–'Modernising Government', UK Government White Paper 1999

6.1 Introduction

This chapter briefly describes the issues around establishing an industrial energy management policy and considers organizational infrastructure, prioritisation and general principles. It then discusses the basic policy options open to governments wanting to influence industrial energy efficiency. It also focuses on the information needed for industrial energy efficiency policymaking and where to go for assistance in policymaking. Specific examples of policies are given and discussed in chapters 7 to 10.

6.2 Organizational infrastructure

Having decided to implement or revamp industrial energy efficiency policy, any government has to consider the institutional framework for that policy. For effective implementation, appropriate institutions must be set up and empowered to plan, implement, monitor and enforce policies, action plans and strategies. All the relevant stakeholders must be included in this process. Typically this involves setting up an energy efficiency agency or department.

Energy efficiency agencies can either be part of a government department or Ministry, or semi-autonomous agencies. It must be borne in mind that energy efficiency often cuts across several traditional departmental or Ministerial boundaries such as energy, industry, transport, economics and construction. This makes siting an energy efficiency agency within government difficult. Although at first sight the natural home would be an energy department or Ministry, this may not be ideal as these departments are concerned with large scale energy supply options and efficiency can sometimes be lost or under-represented within government compared to energy supply.

Chile's National Energy Strategy

Chile's National Energy Strategy 2012 – 2030 recognised institutional challenges by establishing an Inter-ministerial Commission for the Development of Energy Efficiency Policies to help integrate the measures adopted into the policies of each participating entity or institution (Ministerio de Energia, Chile. 2012). This body reports directly to the President of Chile.

The institutional standing of efficiency was also strengthened by the establishment of the Chilean Agency of Energy Efficiency (AChEE).

6.3 Prioritisation

As highlighted in Chapter 1, four intensive industrial sectors typically account for much of the energy consumed by industry: chemicals and petrochemicals, iron and steel, non-metallic minerals and pulp and paper. In some countries specialist industries account for much of the consumption, such as textiles and clothing in Thailand, the Philippines and Myanamar. Focusing on those industries that account for the largest proportion of energy use is an ideal approach.

6.4 General principles

As has been described when reviewing available energy efficiency technologies in Chapter 4 the relevant technologies are mature and well proven, as well as economic in many cases. The challenge for policy makers seeking to improve industrial energy efficiency is to increase the rate of adoption of energy efficiency technologies, i.e. adoption of proven and economic technologies, in order to close the so-called "energy efficiency gap" – the gap between what is economic and what is actually implemented.

Consistency of policy is essential to maintain credibility and to drive investment. Affecting energy efficiency in industry is a long-term process and should be in the context of a long-term target. A good example of this approach is provided by Thailand, which has set a 20 year energy efficiency development plan, starting from 2011 and running through to 2030.

Thailand's 20-year Energy Efficiency Development Plan (2011 – 2030)

Thailand's government developed a national long-term Energy Efficiency Development Plan (EEDP) in 2011 with the objective to:

- Reduce the energy consumption by 5.0 mtoe by 2015
- Reduce the energy consumption by 20% approximately 30 mtoe by 2030
- To lay down strategies and guidelines for energy conservation, to establish the planning framework and the work plan and to allocate the tasks to related government agencies.

The 20-year policy is deployed via the following programmes:

- Implement and enforce energy efficiency regulations and standards
- Preparation and dissemination of information on various techniques for energy efficiency
- Increasing public awareness via various media to increase awareness on energy savings
- Develop the capacity to deploy energy efficiency via training, workshops, and site visits for enterprises, consultants and energy service companies
- Economic incentives for verified energy savings and peak load electricity reduction
- Creation of the one of five most prestigious awards in Thailand: the annual awards for energy efficiency

Singapore also has a long-term plan to reduce its energy intensity by 35% by 2030. This is building on its achievement of reducing energy intensity by 21% between 1990 and 2010. The significant energy and non-energy benefits that result from improved industrial energy efficiency, discussed in Chapter 2, should make it a strategic policy goal with a long-term target.

Singapore's energy efficiency policy and economic incentives

Singapore, a small city state without any significant energy resources, has been dependent on imports of oil and natural gas to meet its energy needs. Energy demand in Singapore is expected to grow due to economic growth and an increasing population. The continual focus on energy supply systems means the country will continue to be vulnerable to insufficient investments in energy capacity and geopolitical conflicts.

Through the implementation of more energy efficient power generation technologies, Singapore has reduced its energy intensity by 21% over a 20 year period from 1990 to 2010. Following on from this success, Singapore has identified and made energy efficiency as one of two key focus areas to meet its future energy needs. The country sees using energy more efficiently and effectively as an alternative to increasing energy production, reduce its dependence on energy imports, enhance its energy security, reducing energy costs and CO_2 emissions.

The government of Singapore developed a suite of energy policies and incentives targeted to further reduce its energy intensity by 35% by 2030. These are:

- Energy Conservation Act 2013: requires businesses consuming more than 15 GWh annually are required to appoint suitably qualified energy managers, report its energy use, and submit plans to improve energy efficiency.

- Energy Efficiency National Partnership (EENP) 2010: provides relevant energy efficiency training courses and workshops, incentives and national energy efficiency awards.
- Grant for Energy Efficient Technologies (GREET): provides financial incentives in the form of a grant to invest in energy efficient equipment or technologies.
- Energy Efficiency Improvement Assistance Scheme (EASe): funds up to 50% of an energy audit when energy efficiency specialists are engaged to identify areas for energy efficiency improvement.
- Certified Energy Manager (SCEM): provides engineering professionals wanting to be energy managers with training and financial assistance to reskill and upskill in energy management in the building or industry sector.
- One-Year Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology (ADAS) to incentivise businesses to replace old, energy-consuming equipment with more energy efficient variant by depreciating the capital cost of in one year instead of three.
- Design for Efficiency Scheme (DfE): encourages businesses planning to build new and/or refurbishing existing facilities to carry out design assessments to meet high standards of energy efficiency standards.

Policy measures should be designed to address the barriers to implementing energy savings that have been identified by enterprises, and take into account other wider policy aims such as industrial growth, social welfare, climate change and economic development. They also need to recognise that enterprises operate in a business environment that is constantly changing. Top management has to make decisions that are based on imperfect information, and perceived risks and rewards.

When designing policy mechanisms, the following national, regional, and economic factors should be considered:

- energy consumption in the industry sector
- structure of industry
- energy intensity of companies, and the ratio of small and medium enterprises (SMEs) to large companies
- availability of financial and human resources in companies
- degree of presence of companies on the global market
- capabilities to support energy efficiency including professional service enterprises, equipment suppliers, energy service companies, etc.
- relevant legal landscape such as greenhouse gas emission regulations
- acceptance of government intervention.

The following general recommendations for policy action to improve energy efficiency in industry have been made by the International Energy Agency through the Renewable Energy and Energy Efficiency Partnership (REEEP 2014).

- to require adherence to energy management protocols
- to promote high-efficiency industrial equipment and systems
- to promote energy efficiency in small and medium enterprises (SMEs)
- to implement complementary policies to support industrial energy efficiency.

In addition, the following policy context throughout the economy needs to be in place or developed:

- establishment of energy efficiency data collection and indicators
- phasing out of subsidies on energy prices for all consuming sectors, except where they contribute to social welfare policies
- leveraging of private investment in energy efficiency
- designation of lead institutions for planning, implementing, and monitoring energy efficiency policies and programmes
- for buildings: building energy codes and minimum energy performance standards (MEPS), aiming for net-zero energy consumption in buildings, improving the energy efficiency of building envelopes, systems, and critical building components
- for appliances and equipment such as motors: requiring minimum energy performance standards (MEPS) and labels for appliances and equipment such as motors, the regular updating of test standards and measurement protocols and measures to accelerate market transformation
- phasing out inefficient lighting products and systems, and phasing in efficient, mainly LED, ones.

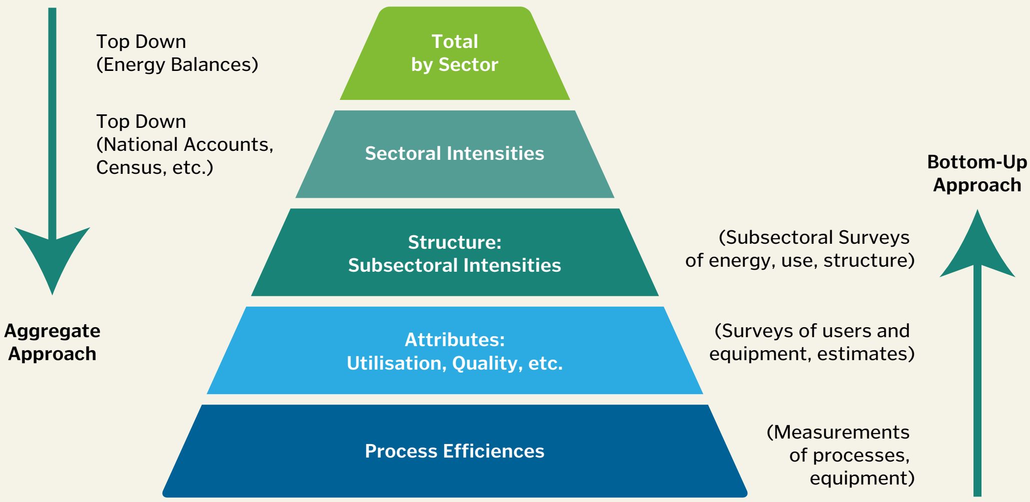
Pioneering industry "champions" for the policies in the private sector should be encouraged to come forward. Their role is to be among the first to implement the measures and run demonstration or pilot projects. This will aid in awareness-raising, and they can subsequently offer training and educational services, and take part in trade fairs, providing rewards for their trailblazing work. Companies also choose to take this role because they recognise the need not just to improve their profitability, but to improve their public image and show they are doing the right thing, thereby demonstrating strong leadership in their field.

Coalitions can be formed of government agencies, businesses and industry associations tasked with implementing specific energy efficiency actions and initiatives, knowledge sharing and raising awareness with training programmes. These coalitions need to involve enterprises within the target industries, the energy efficiency technology and solution providers, lenders and investors and other relevant stakeholders.

6.5 Measuring policy outcomes

A review of 20 energy efficiency policies in Europe (Ecofys 2007) revealed an astonishing lack of data on their performance, costs (both to the government and to companies and consumers) and benefits. In cases where multiple policies were in place, it often wasn't possible to assign the benefits to particular policies. Above all, it was found there was "no such thing as a 'best' policy instrument". Instead, success depended more upon good

Figure 6. Hierarchy of energy efficiency indicators
Source: de la Rue du Can, S. et al., 2007
Note: The width of the pyramid indicates the amount of data required to establish the energy efficiency indicators at the various levels.



design and good implementation. However it was noted that success also depended upon which market barriers were being targeted. The overriding message is to take care, pay attention to detail and follow through.

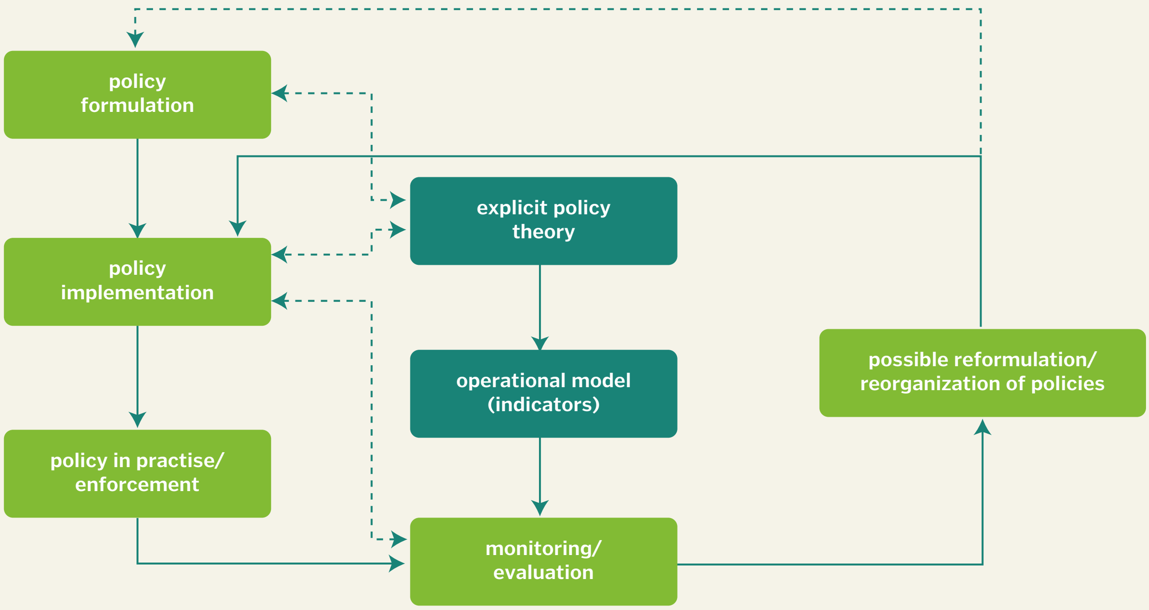
Policy outcomes in all areas need to be measured. Verification systems and reviews of performance need to be built into policies and programmes to ensure maximum effectiveness. Energy efficiency policies are no different in this respect.

Given that the overall objective is to reduce energy use per economic output, this measure – energy intensity – is a highest level measure of performance, but it has to be normalised for changes in the economic structure of the economy. Shifts towards more services and away from industry will improve energy productivity but not necessarily represent an improvement in underlying energy efficiency. To measure actual energy efficiency in industry, and the success of policies designed to affect it, there needs to be a hierarchy of indicators as shown below in Figure 6.

Useful information on the adoption of key technologies can also be gained from monitoring business activity of the energy efficiency equipment supply industry.

Policies should be monitored and evaluated on a regular basis. In the ideal policy cycle, policies are first formulated, implemented and put into practice. They are then monitored and evaluated and the results fed into a re-formulation or even abolition and replacement of policies. Post-policy evaluation is an essential component of the cycle. However, it is

Figure 7. The policy formulation cycle
Source: Ecofys, 2007



important to not change policies too often, medium to long-term stability of policy is essential for both industry credibility and effectiveness. This is particularly important when seeking to influence investment decisions on projects that take time to develop and by their very nature are long term. The policy formulation cycle is illustrated in Figure 7.

6.6 Basic policy options

The basic policy levers available to governments are often characterised as "carrots" (incentives) or "sticks" (regulations and penalties) but in fact there are four basic policy options:

- "carrots" – incentives for energy efficiency which may include financial incentives such as reduced taxes or enhanced capital allowances as well as non-financial incentives e.g. recognition
- "sticks" that penalise companies if they do not improve efficiency e.g. fines, additional taxes or exclusion from certain markets
- introducing regulation to limit choice e.g. only allowing the sale of motors with a certain minimum level of efficiency
- programmes that seek to build capacity and improve the quality of energy management within enterprises.

Industrial energy efficiency policies can be classified into four main categories, although in practice specific policies and programmes often cut across these boundaries. The categories, which we use in subsequent Chapters, are:

- Information-led and capacity-building policies
- Institutional, regulatory and legal policies
- Fiscal and financial policies
- Technology innovation acceleration policies.

Information-led and capacity-building programmes are focused on providing better information to decision-makers about a) the need to invest in energy efficiency b) the potential c) the benefits of energy efficiency and d) specifically how to improve efficiency and increase capacity in energy management. Capacity-building seeks to improve the know-how and capability of industry to develop and implement effective energy efficiency programmes, as well as the capability of other actors such as energy service companies, efficiency technology vendors and the financial sector.

Institutional, regulatory and legal policies are centred on regulating activity in energy efficiency by mandating or prohibiting certain courses of action. Standards for energy management and performance benchmarks are important tools for improving industrial energy efficiency. Requiring large, energy intensive industries and other industrial energy users to conform to ISO 50001 (which was described in Chapter 4) helps to build energy management capacity. Enterprises can also be required to appoint an energy manager and submit energy efficiency improvement plans with monitoring and reporting of energy use and greenhouse gas emissions. Also important tools are benchmarking among industries and their subsectors, possibly implemented through industry associations, and ensuring the sharing of information. As well as regulation of end users, the regulatory framework for the energy supply industry can also be used to improve energy efficiency, for example by mandating certain expenditures on efficiency by energy suppliers, or by regulating tariff design.

Fiscal policies use the tax system to encourage improvements in energy efficiency (or discourage retaining the status quo) and financial programmes seek to increase the flow of investment into energy efficiency projects including by third party investors and lenders. As well as policies specifically designed for energy efficiency, energy pricing policies, particularly where energy price subsidies are in force, will also affect the attractiveness of energy efficiency. Energy pricing decisions clearly have wider economic and social implications.

Although energy efficiency can be greatly improved simply by adopting existing proven technologies, the innovation of new efficiency technologies also has a role to play and can be a source of economic growth. Policies to accelerate innovation in energy efficiency can be developed.

6.7 Sources of help

Policy makers considering implementing or reinvigorating energy efficiency policy can obtain information and assistance from many sources. There are many international networks advocating energy efficiency with expertise and case studies. Some of these organizations include:

- International Energy Agency (IEA)
- Institute for Industrial Productivity (IIP)
- UN's Industrial Development Organization (UNIDO)
- UN's Environment Programme (UNEP)
- UN's Sustainable Energy for All Initiative (SE4All)
- World Business Council for Sustainable Development (WBCSD).

Governments may take advantage of these networks and services to seek advice and partners, best practise and exchanges.

Many of these organizations – and particularly UNIDO – provide detailed guidance on the development of energy management systems and recommend the development of government programmes that require large, energy-intensive industries – and encourage other industrial energy users – to conform to ISO 50001 or an equivalent energy management protocol.

Developing countries are increasingly participating in partnerships and networks involving technology transfer from developed nations. A study of these by the IEA in 2014 found that these technology, sector and fuel-specific networks are rarely established as autonomous, stand-alone entities. Most exist as "opt-in" programmes under wider umbrella initiatives such as the Clean Energy Ministerial (CEM), the International Partnership for Energy Efficiency Cooperation (IPEEC) or the IEA International Low Carbon Energy Technology Platform, among others. This makes them more flexible and responsive to developing countries' needs.

The most common activities of these networks are policy dialogue and building networks of experts or stakeholders, followed by activities aimed at knowledge transfer, such as capacity building or awareness-raising efforts. A small number engage in systematic and comprehensive policy or market analysis.

In the past the transfer of knowledge was mainly from OECD to non-OECD countries, but increasingly there are South-South networks including: China, Brazil and India participating in multilateral co-operation, OLADE, the UN Economic Commission for Latin America and the Caribbean (ECLAC) – an Organization of American States (OAS) programme aimed at encouraging an energy efficiency market in the region, and the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) partnership with the League of Arab States (LAS), and The International Renewable Energy Agency (IRENA) considering options for implementation of the Pan-Arab Renewable Energy Strategy.

Many networks are linked to climate action, such as R20 – Regions of Climate Action – a partnership of sub-national regions working on low-carbon and climate-resilient economic development projects including energy efficiency and energy supply, and C40 – for megacities taking action on large scale projects for reducing greenhouse gas emissions and improving energy efficiency. Both involve partnership with non-government entities, the private sector and research institutes. But more global participation in an energy efficiency initiative is needed.

The Global Environmental Facility (GEF) runs a number of technology transfer projects and has learnt much over the years about ways to maximise chances of success. Following a project aimed at encouraging the use of energy efficiency practices and technologies in the Steel Re-Rolling Mills (SRRM) in India, subsequent recommendations from project evaluators were made. These were that much more effort should be put into getting local players motivated and into capacity building – not just among the targeted enterprises themselves, but also domestic equipment providers, consultants and other key industry players. Additionally, rather than focusing on state-of-the-art technologies, it would be better to devote attention to what are seen by the managers as more appropriate packages of technologies. Finally, that technology transfer must include longer-term capacity-building efforts, a part of a wider process of building up technological capacity and indigenous innovation in developing countries.

Policies can be benchmarked internationally using a number of methodologies, including the ACEEE International Energy Efficiency Scorecard described in the box below.

A tool for comparing energy efficiency policies

The American Council for an Energy Efficient Economy (ACEEE 2014) developed the International Energy Efficiency Scorecard as a way of comparing progress and policies on energy efficiency across countries. The Scorecard covers all sectors of the economy including industry and the 2014 edition covered the world's 16 largest economies (15 countries plus the EU)*, although it is possible for countries to self-score. Within the industry category the Scorecard uses the following indicators:

- industrial energy intensity
- industrial electricity generated by combined heat and power
- investment in manufacturing research and development
- voluntary energy performance agreements with manufacturers
- mandate for plant energy managers
- agricultural energy intensity

Like all indices the Scorecard should be used with caution but it can provide guidance for policy makers considering new policies or reinvigorating existing policies.

*The countries are: Australia, Brazil, Canada, China, EU, France, Germany, India, Italy, Japan, Mexico, Russia, South Korea, Spain, United Kingdom, and USA.

6.8 Conclusions

The overall aim of energy efficiency policy should be to accelerate the rate of improvement in energy productivity (GDP/energy) by increasing the rate of adoption of economically viable energy efficiency measures. In formulating or re-formulating industrial energy efficiency policies, consideration should be given to institutional arrangements such as the type of organization (Ministry, government department or semi-autonomous agency) and where it sits within government. Consideration should also be given to the methodologies for measuring policy success, through industry-specific measures of energy per unit of output (energy productivity), and appropriate sources of information identified. Working with industry sector trade associations can be helpful as a channel to disseminate information and technologies.

Efforts should be prioritised. In many countries a few key industries will consume the majority of energy use and these should be the focus of attention. Even within industry sub-sectors the Pareto law (80/20 rule) will roughly apply, and efforts should be focused on those opportunities with the largest potential.

Broadly, policy makers may deploy policies in the following categories: Information dissemination and capacity building, regulation and enforcement, fiscal and financial support, and technology innovation acceleration. These categories will be explored in turn in the following chapters. In reality many of these policies can and do overlap.

Key points:

- Consider the optimum organization and institutional framework for industrial energy efficiency within government.
- Prioritise efforts – apply the Pareto (80/20) principle.
- Understand specific barriers to improved energy efficiency in specific sectors.
- Establish appropriate top-down and bottom-up indicators of success.
- Benchmark policies internationally and seek assistance.
- Develop policies that combine information and capacity building, institutional, regulatory and legal drivers, and fiscal and financial drivers.

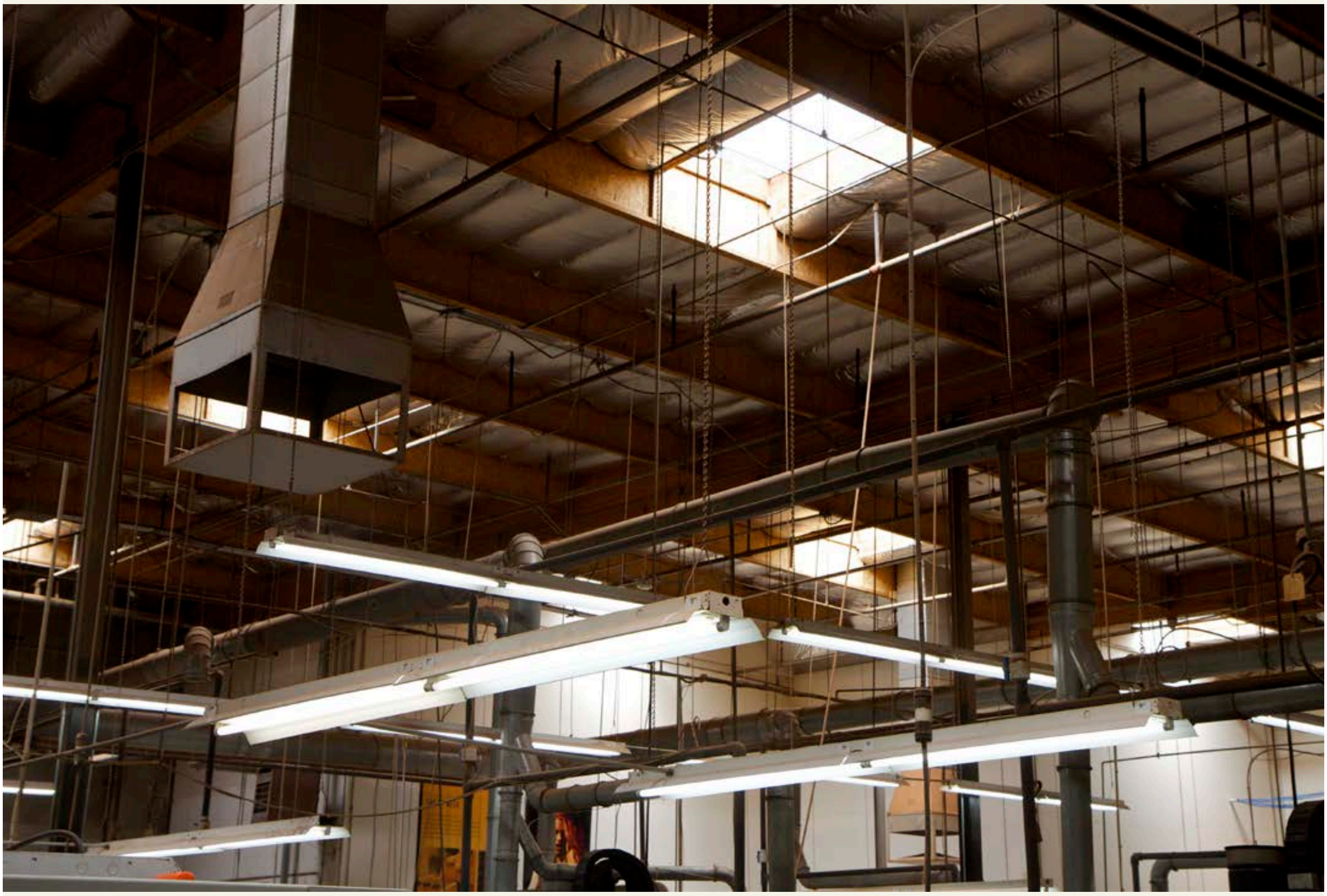


Photo: Marcin Wichary

CHAPTER 7.

Information-led and Capacity Building Policies

"Data is not information, information is not knowledge, knowledge is not understanding, understanding is not wisdom."

– Clifford Stoll

7.1 Introduction

A major barrier to energy efficiency is a lack of knowledge or awareness about the issues surrounding energy efficiency, as we saw in Chapter 5. This deficiency embraces knowledge of the potential, the benefits, available solutions, and energy management techniques. Those lacking such awareness can be in administrations, companies, technical staff and other energy users. This deficit can range from a general "why you should do something" to "what to do" and then in detail "how to do it".

A common core strategy of many national policies is therefore to provide relevant target groups with specified information designed to increase their knowledge and skill level and build their capacity to take effective action. The provision of information has been central to many programmes to promote energy efficiency in industry for many years. Nevertheless it is vital to recognise that simply providing information does not automatically lead to the correct actions. Information is only one component of human decision-making. According to the British Psychological Society (2013):

> "Decisions and subsequent behaviours are not always the product of a rational, deliberative and individual evaluation; they are as likely to be based on opportunistic or emotional impulses, habit and cultural tradition, social norms… as well as a host of other contextual factors, and the structural constraints and opportunities which provide the infrastructure of our lives."

Research suggests that the most effective behaviour change interventions are likely to be those that incorporate financial incentives with non-financial facets, and psychological and non-psychological measures. These may include prioritising high impact actions (i.e. environmentally significant), sufficient financial incentives, effective marketing, meaningful information at critical decision-making points, and quality assurance (Stern 2011). Simply providing information and expecting "rational decision making" will not achieve the desired results.

Traditional types of information programmes were built on a model of communication that saw information passing from the centre to individuals, akin to the old "public service" information model. Although that model has its uses, other approaches, such as peer-to-peer networks, have proved to be effective for maximising learning and effective action. Peer-to-peer networks of like-minded people seem to work because participants give each other not only permission to do the right thing but the conviction to do so, and then support each other in a feedback spiral of improvement. Ireland's Large Industry Energy Network is a good example of an effective peer-to-peer network.

Information provision and capacity-building are closely linked. In practice, both are often part of a larger policy or programme. Information-led and capacity-building policies may provide information through any of the following channels:

- communication and dissemination programmes
- labelling
- training programmes
- encouraging the use of standards such as ISO 50001
- award programmes.

These are each discussed below.

7.2 Provision and dissemination of information

The provision and dissemination of information has been the backbone of many energy efficiency policies and the information provided has covered the why, what and how of energy efficiency:

- motivation to take action (*why* do anything?)
- *what* to do in terms of:
- management systems
- ISO 50001
- specific techniques such as M&V
- technology options for specific industry sectors
- specific advice on *how* to implement management systems and technology.

Channels for information dissemination can be websites or printed material, training sessions, webinars and focused seminars and conferences. Topics covered may include ISO 50001, Measurement and Verification, key cross-sectoral technologies and sector-specific technologies and case studies of companies demonstrating what they did and savings made. It is important that information is seen as independent and impartial. Industry-specific guides should be written with input from industry experts including the appropriate trade associations.

A good example of information provision was provided by the UK's Energy Technology Support Unit (ETSU), formerly an agency of the UK government (now part of a private company Ricardo-AEA with its information being taken over by the UK's Carbon Trust).

For many years ETSU published an excellent series of general and sector specific guides that represent a good model for other countries. These were divided between:

- Energy Consumption Guides – setting out the overall energy consumption picture within the sector and for typical sites
- Good Practice Guides and Good Practice Case Studies – detailing best practice
- New Practice Guides – detailing application of energy efficiency technologies
- Future Practice research and development (R&D) Guides – detailing Research and Development projects.

As well as pure energy efficiency the guides also covered production technologies and technologies that, if applied, would improve energy productivity and save on other costs such as water and raw materials. The titles of the guides in just one industrial sector – metal casting – are shown in Table 14, showing how specific the information was. These guides were developed by Castings Technology International, an independent sector-specific R&D company with 300 member companies across 30 countries. A similar range of guides was produced and disseminated across many industrial sectors.

Table 14. Energy efficiency publications in the UK casting industry
Source: Castings Technology International, 2015

ENERGY EFFICIENCY	
Energy Consumption Guides	
ECG038	Non-ferrous Foundry Industry
ECG048	UK Iron Foundry Industry
Good Practice Guides	
GPG017	Achieving High Yields in Iron Foundries
GPG050	Guidance Notes for the Efficient Operation of Coreless Induction Furnaces
GPG058	Cupola Melting of Cast Iron in Iron Foundries
GPG063	Metal Distribution and Handling in Iron Foundries
GPG068	Electric Holding of Hot Metal in Iron Foundries
GPG142	Improving Metal Utilisation in Aluminium Foundries
GPG0166	Energy Savings in Foundry Services
Good Practice Case Studies	
GPCS036	Computer Simulation of Solidification in Non-Ferrous Sand Foundries
GPCS037	Computer Simulation of Solidification in Ferrous Industries
GPCS112	Gas-fired Shaft Furnaces
GPCS131	Computer Simulation of Solidification in Steel Foundries
GPCS161	Cupola Melting of Cast Iron
GPCS213	Demonstrating Good Practice in Medium Frequency Coreless Induction Furnaces

GPCS218	Corundum Resistant Furnace Lining
GPCS282	Use of Molten Metal Filters in Non-ferrous Foundries
GPCS344	Energy Savings from Small Efficient Melting and Holding Furnaces
GPCS349	Ladle Lining with a Lightweight Insulating Refractory Material
GPCS353	The Use of Filters in Ferrous Industries
New Practice Guides	
NPCS105	Efficiency meter provides savings for an induction melting foundry
Future Practice R&D Guides	
FPP037	Development of computer aided engineering for use in foundries
FPP047	Quantifying important factors in iron melting in medium frequency coreless induction furnaces
FPP172	RIMLOC: Rapid Induction Melting – Lost Crucible
SECTOR-SPECIFIC FOUNDRY PUBLICATIONS	
Management of Foundry Sand	
GC003	Sand Costs Reduced by Thermal Reclamation
GC099	Small Foundry Benefits from Investment in Sand Reclamation
EG004	Chemically Bonded Sand: Use and Reclamation (an Environmental Performance Guide)
ECG005	Foundry Greensand: Use and Reclamation (an Environmental Performance Guide)
Management of Chemical Binders	
GC023	Improved Process Control Reduces Mould Losses
GC035	New Sand Binder System Reduces Foundry's Costs and Emissions
Management of Organic Emissions	
GC014	Profit from Water-based Investment
GC068	Filter Out Black Smoke Emissions
GENERIC FOUNDRY PUBLICATIONS	
Environmental Management Systems	
GC04	Environmental Management Systems in Foundries
GC049	Environmental Management System Improves Performance
GC059	Environmental Improvements Reduce Costs

Although these guides have not been maintained due to changes in emphasis and structures within UK energy efficiency policy, they remain an excellent model for both content and methodology for other countries. Given the advent of the internet, similar guides are more easily published and disseminated online today rather than in hard copy.

To be effective, information should always be targeted for the specific audience, taking into account their interests, job responsibilities and educational levels. Information should also ideally be combined with other behaviour-change reinforcements especially, where possible, incentives. These do not have to be financial (see 7.6 below). An example of an information campaign that did this successfully comes from Ireland's "Power of One at Work" initiative.

Ireland's "Power of One at Work" initiative

"Power of One at Work" initiative encouraged SME employers and employees to be more energy efficient. It provided basic guidance on energy efficiency using an advertising campaign, a website and a toolkit for implementing a workplace energy awareness campaign at the local level. This approach was hands-on and proved successful. Over 2007-2011 it supported 1,470 SMEs with 130,000 employees. In 2012, 200 SMEs with 2,000 employees were supported, achieving cost reductions of EUR 2 million from a total EUR 19.7 million energy bill (IEA 2014b).

A good example of a peer-to-peer communication network is Ireland's Large Industry Energy Network.

Ireland's Large Industry Energy Network (LIEN)

Facilitated by the Sustainable Energy Authority of Ireland (SEAI), the Large Industry Energy Network (LIEN) is a voluntary group that is working to develop and maintain robust energy management. It consists of 166 large energy users representing approximately 17% of Ireland's total primary energy consumption. Members have an annual energy spend of approximately EUR 1.1bn (SEAI 2015). Members are committed to:

- developing an energy management programme
- setting/reviewing energy targets
- undertaking an annual energy audit
- reporting annually on energy performance.

Over 70 of these companies are also members of a separate SEAI initiative, the Energy Agreement Programme, and are now working towards achieving the standard ISO 50001.

Having been in operation for over 10 years, LIEN organises regular networking events, workshops, seminars and site visits. These provide the opportunity for members to meet and learn from specialists, including energy experts and their fellow energy managers, on the solutions that work. By learning from experts and sharing knowledge and experiences, members save valuable research time, invest wisely and maximise returns.

SEAI also provides a range of reports, case studies, statistics, benchmarking data and tools, such as the Energy MAP tool – to facilitate energy assessments – and an Energy Management Maturity Model. This helps enterprises understand how far they have progressed with developing their EnMS, and how it can be continually improved.

Independent analysis has found that these companies reported faster energy performance improvement, despite not being new to energy management and having already achieved significant savings over a previous 10-year period, without the use of an energy management standard (IIP & IEA 2012).

A key outcome of the LIEN has been the demonstration that the majority of a company's energy savings can come from operational changes alone rather than from capital-intensive equipment-related projects.

7.3 Product labelling

Product labelling is another method of providing end users with information.

Energy efficiency product labelling programmes, when used in conjunction with energy efficiency standards, are effective and complementary measures which help to transform the market. To remain effective, they must be regularly revised and updated to stimulate technical progress and ensure a steady improvement in energy efficiency. In this respect, one way of establishing dynamic standards is to relate them to the most efficient appliances on the market.

A good example is the European Union's Eco-design Directive and Energy Labelling Directive.

European Union's Eco-design and Energy Labelling Directive

The Energy Labelling Directive 2010/30/EU was adopted by the European Parliament and Council in May 2010. It extended existing labelling rules to the commercial and industrial sectors.

Any energy-consuming product, including equipment, buildings and transport vehicles with sales of more than 200,000 units per year in the European Community, is required to comply with the Eco-design directive (2009/125/EC) and Energy Labelling Directive (2010/30/EU). By setting these standards at European rather than National levels, manufacturers do not have to navigate through multiple national regulators on the market. As an alternative, industry sectors may also sign voluntary agreements with the European Commission to reduce the energy consumption of their products through their life cycle.

The eco-design directive requires these products to have their energy consumption and greenhouse gas (GHG) emissions calculated for their life-cycle at design stage. In addition, the Directive also sets out minimum mandatory requirements for the energy efficiency of these products through a series of product-specific regulations and test methods. Products that do not meet these regulations and standards are not allowed to be sold in the European market. A timeline for phasing out the least energy efficiency products is also specified in the product-specific regulations.

The product documentation, test methods and test results need to be submitted to the European Commission for approval. The approval of the product is indicated by a CE marking and an EC declaration of conformity for the product. This contains the following information:

- description of the product and its use
- test methods and results to the assessments
- elements of the product design specification
- list of the appropriate standards
- copy of the information.

Suppliers must also prepare and display an energy label for the product prior to it being placed in the market as mandated by the Energy Labelling Directive. The labels, containing a series of seven energy efficiency categories, are colour- (red to green) and alphabet- (G to A) coordinated as specified in each product-specific regulation. A product rated 'G' or 'red' has the lowest energy efficiency ratings. A product rated 'A' or 'green' has the highest energy efficiency ratings.

There is a wide range of products that have to be labelled under the Directive. For the industrial sectors the most relevant are:

- motors, pumps and fans
- distribution and power transformers
- air conditioning units
- personal computers
- lighting.

Labelling schemes are widely used in many countries, although they tend to be focused on appliances and consumer goods rather than industrial equipment. Some countries include motor and pumps. For example China operates a labelling scheme similar to the EU's which includes electric motors. In Mexico, CONUEE, the National Commission for the Efficient Use of Energy (an agency of the Secretariat of Energy), has established an extensive mandatory labelling scheme that covers many types of residential appliances and industrial equipment including centrifugal pumps (APERC 2012).

Table 15. How different people exert different influence on energy efficiency

Job roles	How they influence energy efficiency
General	Awareness of energy consumption and ways to save energy
All employees	Appropriate operation and maintenance of energy using equipment and infrastructure
Functional managers	Effective planning, scheduling, purchasing and of energy using equipment
Energy managers	Disseminating the appropriate information to the various stakeholders
Boardroom	Strategic view of the business, governance structure, and allocation of resources
Consultants	Correct identification and evaluation on energy efficiency opportunities
Equipment suppliers and installers	Correct and timely installation, commissioning of the energy efficiency project

7.4 Capacity-building through energy management training

Building the capability to understand, develop and implement energy efficiency opportunities and their value to the enterprise is a critical way of overcoming the informational barriers to energy efficiency. Training is vital to this. Different types of training need to be targeted at different audiences within enterprises, since different roles exert different influences on energy efficiency (as shown in Table 15).

Specific training can be developed that covers the different functions and steps within an effective EnMS including: Energy Auditing, Measurement and Verification, and Building Business Cases. Training on specific technical opportunities can also be developed. Standard qualifications for energy managers can be developed and government can assist appropriate institutions to develop and accredit courses. The UK Energy Institute has a range of energy management qualifications as shown in the box below.

UK Energy Institute's Energy Management Training Portfolio

The Energy Institute offers a three level energy management training portfolio as follows:

Level 1: Energy Management Certificate

A five-day practical introduction to energy management recommended for those new to an energy management role or those taking on energy management responsibilities in an existing role for the first time. Available in classroom or online format. Topics covered include:

- Introduction to energy management – building an energy management system
- Metering and buying
- Metering, monitoring and targeting techniques
- Regulations and standards
- Energy auditing in practice
- Energy auditing – report writing
- Energy management solutions
- Energy management project development
- Renewables
- Mounting an effective staff awareness campaign.

Level 2: Energy Management Professional
A 150 hour online course providing all the knowledge and skills required of a professional energy manager. Recommended for those with two or more years experience in a related role. Core modules include:

- The role of an energy manager
- Heat transfer
- Fuels and combustion
- Finance
- Monitoring and targeting.

In addition ten electives have to be taken selected from courses on:

- Heating and ventilating
- Air conditioning and refrigeration
- Lighting
- Motors and drives
- Thermal comfort and building physics
- On-site electricity generation
- Building Management Systems
- The energy industry and energy costs
- Regulations and incentives
- Energy auditing
- Metering and verification
- Data testing and analysis
- Energy management and transport
- Electricity grids
- Energy and the environment
- Energy management systems and standards
- Carbon management plans
- Water systems and auditing
- Compressed air
- Financial appraisals
- Process heat and steam.

Level 3: Advanced Energy Manager
A 12-day classroom course for experienced energy managers covering project management and key technologies. Recommended for those with three or more years experience in an energy management role. Topics covered include:

- Monitoring and targeting
- Energy costs and project management
- Energy fundamentals
- Energy procurement
- Implementing and auditing ISO 50001
- Energy and emissions laws and trading
- Space heating
- Energy in buildings
- Staff awareness
- Process heat, steam and heat recovery
- Combined Heat and Power
- Air conditioning
- Refrigeration
- Lighting
- Compressed air
- Renewables.

The Energy Institute also offers the status of Chartered Energy Manager. This is the gold standard in energy management in the UK and is available to those who achieved Level 3 certification, have five or more years' professional experience in a relevant role, and meet other standards of the Energy Institute and the UK Engineering Council (which governs professional engineers). In addition, the Institute also offers a range of specialised courses, for example focused on ESOS (the Energy Savings Opportunities Scheme).

ESOS is discussed in Chapter 8.

A new initiative from the UK, the Junior Energy Management Apprentice scheme, addresses the critical issue of training junior staff to address potential future shortages of qualified energy managers and engineers.

United Kingdom's Junior Energy Management Apprentice Programme

The Junior Energy Manager Apprenticeship Programme started in 2015. The development of the Junior Energy Manager Apprenticeship Standard has been supported by a strong group of small, medium and large enterprises from different industries, professional institutes, and coordinated by the UK Energy Managers Association under the auspice of Department for Business, Innovation and Skills (BIS)*.

The Junior Energy Manager Apprenticeship Programme diploma qualification is open to those interested in becoming energy managers, and newly appointed energy managers.

The apprenticeship operates on a day-release basis where the candidates are released from work for one-two days per week to attend in-class training and assessments. The remaining days are spent working in the company, and on self-study.

Classes are provided by several institutes, associations, further education colleges and independent training providers, and are designed to develop a broad range of basic skills in energy assessment and measurement of energy consumption, technical and operational energy management issues, energy management strategy, regulatory and legal compliance, reporting and communicating the status of energy performance and progress of improvements.

Up to two-thirds of the tuition fees are funded by the Government and the remaining by the apprentice's employer. During the 24-month long scheme, the apprentice should be employed or have access to facilities to complement and practice the skills taught.

At the end of the 24-month apprenticeship, and upon successful completion of the end-of-programme project, the candidate can be granted a diploma and is eligible to join several professional associations and institutes as an energy management technician and a recognised energy manager. The apprenticeship programme also acts as a bridge to undergraduate and postgraduate level energy management and other specialist qualifications in the United Kingdom.

* The UK government Ministry overseeing industry.

7.5 Capacity building by promoting standards such as ISO 50001 and IPMVP

As discussed in Chapter 4, ISO 50001, the international standard for energy management, is an important tool for building energy management capacity within industry (as well as other sectors). Government can design policies and programmes to support the adoption of ISO 50001, as well as other standards such as the International Performance Measurement and Verification Protocol (IPMVP). These programmes are usually voluntary in nature although potentially adoption of ISO 50001 could be mandated, either directly or through procurement rules.

The United States' Superior Energy Performance (SEP) is an example of a programme to promote adoption of ISO 50001. A global version of SEP has been created – Global Superior Energy Performance (GSEP) – and has been incorporated into G20's Energy Efficiency Action Plan (G20 2014). Policy makers can design programmes to encourage adoption of GSEP.

United States' Superior Energy Performance (SEP) programme

Superior Energy Performance (SEP) programme, managed by the United States Department of Energy, is an extension of ISO 50001, and includes additional requirements specified in *ANSI/MSE 50021 Superior Energy Performance - Additional Requirements for Energy Management Systems* and an external verification of achieved energy performance improvement.

An independent third party accredited by the American National Standards Institute (ANSI)-ASQ National Accreditation Board (ANAB) audits each facility to verify achievements and qualify it at the Silver, Gold, or Platinum level, making it a transparent process. The criteria for Silver, Gold, or Platinum levels are as follows:

- Silver – 5% improvement over 3 years
- Gold – 10% improvement over 3 years
- Platinum – 15% improvement over 3 years.

As of April 2015, nine companies have obtained Platinum, eight are at gold and eleven are at silver status (US DOE 2015). Preliminary results from SEP reports an average 10% reduction in energy costs within 18 months of implementing SEP, giving annual savings of between USD 87,000 and USD 984,000 using no- or low-cost operational measures. In addition, the split between energy savings due to capital and operational energy performance actions changed following facility participation in the SEP programme. Prior to SEP participation, the average split between capital/operational projects was 36/64, which shifted to 26/74 after SEP implementation (Therkelsen et al. 2013).

SEP case studies

One published case study (Clean Energy Ministerial 2013) involves Cummins, a global manufacturer of diesel engines and related technology. Its North Carolina-based site achieved Gold level certification. Average energy performance was increased by 12.6% over three years. Measures costing USD 248,000 returned an annual energy cost saving almost three times higher at USD 716,000. This cost was paid back within 11 months from operational improvements in energy management alone. A rigorous business system now proactively manages the use of energy.

Motivation for signing up to the programme was chiefly because this particular facility accounted for 10% of energy use within the company. Therefore significant savings were potentially available. Cummins also had a company-wide goal of reducing energy use by 25% and greenhouse gas emissions by 27% by the end of 2015 compared to 2005. The entire plant was metered (and sub-metered) for monitoring purposes. The external verification of savings helped to make management more favourable to continuing to fund energy efficiency programmes. An Energy Champion programme was instituted to train staff to become professionals in improving energy efficiency.

Amongst the lessons learned was the value of assigning individuals clear responsibilities for achieving results. The training was supported by the US Department of Energy, which also supported the use of an Energy Performance Indicator regression analysis tool. This tool is able to track improvements while accounting for variations due to weather, production and other variables. The baseline from which improvements were calculated represented business-as-usual level of energy consumption, production taking into account heating/cooling degree days and other relevant variables. Two projects alone required little or no capital spend and saved 1.2 GWh in on-site energy usage in the first year.

Cummins is now participating in the SEP Enterprise-Wide Accelerator programme, designed to implement ISO 50001 across an entire corporation to achieve economies of scale. This lets facilities share best practices, best integrate the necessary elements into company practices and accelerate deployment of training and tools company-wide.

GSEP Energy Management Working Group case studies

Case studies[6] from the Global Superior Energy Performance (GSEP) Energy Management Working Group (EMWG) document how one U.S. plant, HARBEC, Inc., and two Canadian plants, IBM and Lincoln Electric, deployed ISO-compliant systems:

HARBEC, Inc. improved the energy performance of its speciality plastics manufacturing plant in upstate New York by 16.5%. Primarily this involved managing its combined heat and power (CHP or co-generation) unit more efficiently. The work earned HARBEC SEP Platinum certification. The USD 127,000 cost was paid back by the resulting operational energy savings within 2.4 years. The EnMS now saves the plant 6 billion Btu (6,300 gigajoules) and USD 52,000 each year by using a real-time automated monitoring system.

IBM implemented an EnMS at a manufacturing facility in Bromont, Quebec, that was certified for conformance with CAN/CSA ISO 50001 in 2013. The EnMS helped it to implement 36 energy efficiency projects that reduced energy consumption by 9.2% and saved CAD550,000 in that year. Tool modifications generated approximately 27% of the savings, while heating, ventilation and air conditioning and exhaust reduction projects generated the remaining 73%.

[6] *Available at http://www.cleanenergyministerial.org/Our-Work/Initiatives/Energy-Management/Case-Studies*

Lincoln Electric's EnMS achieved CAN/CSA ISO 50001 certification as well. This helped it reduce energy consumption by 22% in 2013 at its facility in Toronto, Ontario. The facility manufactures steel welding wire and industrial diesel-driven DC generator welding machines. Managers were initially interested in an EnMS as a means to maintain competitiveness and reduce risks associated with volatile energy prices. But they soon learned that its successful EnMS implementation owed much to its progressive corporate culture. This actively encourages the identification of energy improvements and conservation measures. Lincoln Electric now expects its EnMS to lead to continuous improvement in overall plant energy consumption.

Although strictly not a national energy policy instrument, the work of UNIDO is also a good example of how ISO 50001 can be used to drive energy efficiency. UNIDO works in (as of April 2015) 25 countries to support their capacity development in energy management and the model used is integral to how many countries utilise ISO 50001 and energy audits to shape their policies.

Capacity building and implementation support from UNIDO

UNIDO promotes energy management by offering training and implementation support in Energy Management Systems (EnMS) and best available technology in energy system optimisation (ESO).

It has assisted over twenty countries in implementing ISO 50001 and double that number for low-cost EnMS-ESO projects. It is also working on mechanisms to enhance financing for investment in energy efficiency and low carbon technology and trains lending offices in banks to help them spot opportunities for profitable investments in industrial energy efficiency.

UNIDO programmes for the steel industry, for example, are delivered in Ecuador, Egypt, Iran, Malaysia, Philippines, Russian Federation and South Africa, where it runs awareness seminars, training for users and experts, working with local consultants and partner enterprises. Training is based on the use of resources and tools that are outlined in UNIDO's *Practical Guide for Implementing an Energy Management System* (UNIDO 2013b). They include webinars and plant visits.

As an example, in South Africa UNIDO has helped to save 460 GWh in 2011-2014 at Arcelormittal Saldanha Steel Works, which has a peak energy demand of 160MW. This entailed improvements in the post-combustion cooling fan system, LPG consumption, water-cooling system, compressed air systems and the ladle heating station system, as well as general awareness-raising in energy efficiency.

In Egypt, work included benchmarking the entire iron and steel sector, based on data collected from participating companies who account for 76% of production in the country.

Another example of a capacity-building programme is given by the US Better Buildings, Better Plants Program.

United States' Better Buildings, Better Plants

Launched in April 2011, the U.S. Department of Energy's (USDOE) Better Buildings, Better Plants programme (commonly referred to as the Better Plants) is a voluntary initiative to drive significant improvement in energy efficiency across US industry. Any manufacturing plant in the U.S. can participate in the programme. It aims to drive a 25% energy intensity reduction over a 10-year period. A company's CEO or other senior executive has to sign a two-page partnership agreement which commits the company to:

- Adopt a corporate-wide energy intensity goal over a 10-year period
- Establish an energy use and energy intensity baseline
- Develop an energy management plan
- Designate an energy leader or energy manager
- Report energy intensity, energy use data, and achievements annually.

In exchange, the USDOE agrees to support the company to achieve the energy intensity reduction by providing the following:

- Technical training to develop energy management plans, identify energy-saving opportunities, track energy performance metrics against its energy goal
- Access to USDOE energy analysis software tools, training webinars, technical guidance documents, and peer-to-peer networking opportunities.

The technical support assistance comes in the form of three-day on-site workshops led by Better Plants experts. The expert trains participants on how to identify, implement, and replicate energy-saving projects. The training is system-specific and organised around:

- Compressed air
- Fans
- Motor-driven systems
- Steam
- Process heating
- Pumps
- ISO 50001 energy management system.

Companies that meet the 25% target will receive recognition from USDOE in the form of certificates of achievement, letters, and other items presented by USDOE at conferences or other events. They are also encouraged to set a new goal in partnership with the Better Plants programme. Companies that do not meet the 25% do not attract any penalties.

As of 2015, the Better Plants programme consists of 150 companies spanning 2,300 facilities. These represent nearly 11% of the U.S. manufacturing energy footprint. 13 of the companies are listed as Fortune 100 companies. 765 people have participated in the training and have identified an energy savings potential worth 2.7 TBtu per year with a financial value of USD 14 million per year. The reported energy savings by companies show an average energy intensity reduction of 2.4% per year.

7.6 Recognition and reward programmes

Recognition and reward programmes give much needed publicity and awards to individuals and teams that produce outstanding energy efficiency results. They can also introduce an element of competition to further enhance efforts to improve energy efficiency. Many examples exist throughout the world. They can be run at the national (government agency) level, sectoral or trade association level, or within companies.

It is important with national award schemes to clearly determine what features are to be recognised and rewarded. Many types of recognition schemes are possible and they can use quantitative and qualitative measures. China's scheme judged manufacturers purely on quantitative metrics for the efficiency of appliances that they produced for consumers. The US Energy Star programme incorporated qualitative judgements as well. The Japanese awards include multiple round of judging and often site visits. While Japan's programme rewarded innovative and outstanding products, the US scheme evaluated the entire catalogue of Energy Star products that a single manufacturer offered.

In Germany, the Initiative EnergieEffizienz campaign, established by Deutsche Energie-Agentur – the German Energy Agency – (dena), honours outstanding energy efficiency projects in industry and commerce with an annual Energy Efficiency Award. Public or private companies and institutions are recognised for implementing exemplary innovative measures in their facilities to increase energy efficiency. Crucially, one of the criteria is transferability of a measure to other companies. This evaluates the market potential of the energy efficiency measure either in the same industry or in other industries.

Third party awards can also be supported by government. An example of a third-party award, now in its 16th year (2015), is the UK Energy Institute's annual Environment and Energy Awards. These recognise and celebrate excellence, innovation and best practice within the energy industry and include awards for:

- the energy manager of the year, who is effective not just within his or her company but within the industry as a whole
- the energy products or service award, rewarding one which demonstrably offers significant energy saving benefits
- the innovative energy efficient project award, for a project which shows an innovative approach through the planning, development and implementation stages

- and the business utility of the year award, which recognises utilities that demonstrate commitment to helping business users improve their water or energy efficiency and management.

Another example is the annual Power & Electricity Awards Asia, which celebrates and honours the contribution from individuals and enterprises toward the growth of the power, energy & utilities sector in Asia Pacific area and includes a category for "Best Asian Energy Efficiency Project of the year". In the same part of the world, the ASEAN Centre for Energy in Jakarta coordinates the Energy Awards, which are bestowed every year upon the most energy-efficient buildings in different categories.

7.7 Conclusions

Information provision, training programmes and awareness-raising are vital, in engineering and technical issues and with the aim of changing behaviour. Peer-to-peer networks are extremely effective in this regard. However, providing information alone is unlikely to result in effective action unless it is linked to other factors such as incentives. Labelling of products is a useful tool for providing appropriate information at the point of decision making. Most labelling programmes are focused on appliances but also include important industrial equipment such as electric motors and pumps. Recognising and rewarding successful energy efficiency programmes and projects in industry can be a useful and relatively low cost way of spreading information and motivating action. Information provision and capacity-building can also be a component of other policies including fiscal and financial policies. These are explored in the next chapter.

Key points:

- Provision of information is a key strategy to overcome the barrier of lack of knowledge but information alone is not enough to drive action.
- Information should cover the benefits of efficiency, establishing energy management systems and specific technologies.
- Information dissemination can be peer-to-peer as well as hub-to-spoke.
- Product labelling is an important way of providing information and can be applied to industrial products as well as appliances.
- Training is an important tool for capacity building.
- Promoting standards such as ISO50001 is an important tool for building capacity.
- Award and recognition programmes have a role to play in information dissemination and inspiring action.

Photo: Joxemai

CHAPTER 8.

Institutional, Regulatory and Legal Policies

"The end of law is not to abolish or restrain, but to preserve and enlarge freedom. For in all the states of created beings capable of law, where there is no law, there is no freedom."

– John Locke

8.1 Introduction

Governments may drive energy efficiency through laws and regulations that require enterprises to take certain actions or face legal consequences. They can also use their convening power to create or catalyse institutions with the task of assisting companies to improve their energy efficiency. This chapter examines the various types of regulations that can be applied to industrial sectors and the energy supply industry to encourage industrial energy efficiency. It also considers voluntary agreements. Evidence shows that all these approaches can be effective, but mandatory approaches more so. These, however, require enforcement mechanisms.

According to the IEA's 2015 World Energy Outlook (IEA 2015b) the extent of mandatory energy efficiency regulations has spread significantly over the last 10 years: "from covering 14% of the world's energy consumption in 2005 to 27% in 2014. Efficiency regulations now cover 36% of industrial energy use, up from only 3% in 2005, driven by new mandatory targets in China and India". These mandatory regulations will increasingly impact on levels of industrial energy usage. Despite this progress there is still a long way to go, with 64% of industrial energy usage *not* covered by regulations, and much to be done to improve the effectiveness of regulations. Countries can learn a great deal from each other on the effectiveness of energy efficiency regulations, as well as other institutional topics.

A menu of the possible institutional, regulatory and legal policies would include:

- voluntary agreements
- mandatory measures including:
  - energy performance targets
  - energy audits
  - energy managers
  - mandatory reporting
  - trading
  - adoption of standards like ISO 50001
- Minimum Energy Performance Standards ("choice editing")
- obligations on energy suppliers to invest in energy efficiency.

These are discussed below individually but in practice they can be, and often are, combined.

8.2 Voluntarily negotiated agreements

Government energy efficiency agencies can establish voluntary agreements with individual enterprises or industrial sub-sectors to establish energy efficiency targets. As well as targets, the agreements can include guidance and/or assistance with establishing energy management systems as well as specific technologies.

In establishing voluntary negotiated agreements on energy performance, policy makers must guard against the natural tendency of enterprises and industries to want a low level target, i.e., one that is easily achieved and possibly in line with a Business As Usual (BAU) scenario – what would have happened without an agreement. Arriving at the appropriate level of target requires negotiation skills and a sound evidence base for target setting, founded on detailed knowledge of the industry and its technical and economic potential for energy efficiency. Policy-making and enforcing agencies are likely to require specialised outside assistance to establish appropriate targets which are both ambitious and achievable.

Independent post-action evaluations or verification of these voluntary agreements are rarely carried out. Where they have been, their effectiveness is judged to be uncertain. Even in the Netherlands, where there have been long-term agreements with the industrial sector and benchmarking covenants, an independent evaluation concluded that they delivered only about 25-50% of the observed decrease in industrial energy intensity. The World Energy Council (2012) concluded that although this was a good result, it was achieved by a combination of large public and private effort. It added that most other similar agreements probably achieved considerably less impact.

8.3 Mandatory measures

A range of mandatory measures can be used to help drive industrial energy efficiency more effectively. These include:

- energy performance targets
- energy audits
- energy managers
- reporting
- trading
- adoption of standards such as ISO 50001.

Often these are combined with other policies such as fiscal policies.

Any mandatory measure raises the issue of how to ensure compliance. Policy makers therefore need an understanding of how to develop and implement appropriate compliance systems. These will need to be adequately resourced.

8.3.1 Mandatory energy performance targets

Mandatory energy performance targets require enterprises to achieve set levels of performance within a certain time frame. It is critical to establish the appropriate measure of performance and determine those variables that affect energy performance but are outside the control of enterprise management, e.g. weather or levels of sales (and hence production levels) which may be affected by external factors such as the general state of the economy. Performance indicators may also need to consider product mix in multi-product situations.

China's Top 1,000 Energy Consuming Enterprises Programme is an example of mandatory target setting. The programme also included mandatory audits. Information on the Top 1,000 Energy Consuming Enterprises programme and the follow-on Top 10,000 Energy Consuming Enterprises programme is given in the box below.

China's Top 1,000 and Top 10,000 Energy Consuming Enterprises programmes

China's top 1,000 programme was launched in 2006. It was designed to save 100 million tonnes of coal equivalent (mtce) over five years (2006 - 2010) in the largest 1,008 enterprises. It was part of China's 11th five year energy plan to achieve a 20% reduction in energy intensity (energy/GDP) (IIP 2015). The 1,000 companies were defined as those consuming a minimum of 180,000 tonnes coal equivalent (tce) per year. They had to set up energy monitoring systems, carry out energy audits to identify opportunities for significantly reducing their energy intensities, prepare energy efficiency plans, and submit all these for analysis.

China's Industrial Energy Performance Standards set out the mandatory minimum energy intensity values for existing plants and new builds, taking into account different types of raw materials, fuels, and throughputs. The rules also allowed companies to aim for more ambitious, voluntary, energy intensity standards.

The measurement and reporting system's data and statistical analyses were used to compare enterprises' energy performance against the minimum expected energy performance. The energy audits identified opportunities for improvements and their feasibility and they generated plans for implementation within six months of the programme.

Enterprises were then required to review and submit their energy efficiency plans, energy consumption reports, and the cost-effectiveness of energy efficiency improvements every year. They were supported by provincial and local governments via the provision of energy management training, other assistance and financial support. Enterprises that failed to achieve their minimum targets were issued a "notice of criticism". As a consequence, these enterprises were subject to the threat that official approval of any capital projects or additional industrial land use requests could be suspended, and that economic sanctions might be applied. If the enterprise was state-owned, the leadership and management team also came under pressure from the state agencies.

Provincial and local government departments and officials were measured each year in terms of the collective energy performance improvement of the large enterprises in their jurisdiction. If the targets were not achieved, the relevant government officials also became ineligible for rewards, honorary titles, and/or promotion.

Evaluation of the programme by the Institute for Industrial Productivity found total energy savings for the Top 1,000 enterprise programme to be estimated at 150 mtce. This was 50 mtce more than originally targeted. China's 12th five-year energy plan extended the programme to the country's top 10,000 enterprises between 2010 and 2015. The programme actually included more than 15,000 enterprises (each consuming more than 10,000 tonnes of coal equivalent (tce) per year), 160 large transportation enterprises, and public buildings (each consuming more than 5,000 tce per year), giving a total of 17,000 large enterprises.

It was designed to achieve an average 16% reduction in energy intensity and an energy saving of 250 mtce, contributing 37% to China's energy savings target.

The following requirements were in addition to those of the completed Top 1,000 programme:

- Provincial and local governments to publish the results
- Enterprises consuming more than 10,000 tce per annum were mandated to achieve the world-class energy intensity standards specified in Industrial Energy Performance Standards
- Establishing and implementing an energy management system
- Provision of financial aid to energy efficiency projects
- Introduction of energy performance contracting and energy service companies.

The programme was designed to:

- Set minimum energy performance expectations for large enterprises
- Increase knowledge on ways to use less energy
- Increase awareness of energy consumption through systematic analysis and reporting of energy consumption and opportunities for improvements
- Accelerate the phasing out of energy inefficient technologies.

Financial incentives were provided for energy saving projects on the basis of a fixed payment (200 RMB/ 30 USD, 22 EUR) per tonne coal equivalent saved per year. No incentives were provided for supporting activities such as conducting energy audits, training or implementing energy management systems. Considerable effort was put into capacity-building through structured training programmes.

An evaluation of 16,078 enterprises in 2012 (half way through the programme) showed that total energy savings were 170 Mtce, 68% of the total target. 26% of the enterprises exceeded their energy savings targets and more than 50% had met their targets.

Although mandatory targets can clearly be effective in driving improved industrial energy efficiency they must be designed with care if they are to be effective. They are more associated with command and control economies such as in the former Soviet bloc, where energy efficiency agencies were really enforcers of consumption targets. They also run the risk of failing to take into account rapidly changing market conditions that lead to changes in production volumes and product mixes.

8.3.2 Mandatory energy audits

Mandatory energy audits comprise an important policy tool that requires obligated parties to undertake energy audits in order to identify opportunities for improving energy efficiency.

Mandatory energy audits under the European Union's Energy Efficiency Directive

The Energy Efficiency Directive (2012/27/EU) is one of the most ambitious directives in the European Union. It sets out to achieve 20% reduction in energy use (368 mtoe) across the whole community and places requirements on governments, power plants, and large enterprises.

The directive requires all large enterprises in Europe to carry out an energy audit by 5 December 2015 and every four years thereafter. The Directive also allows enterprises with ISO 50001 certified management systems covering the whole enterprise's energy consumption to be exempt from carrying out an energy audit.

The United Kingdom's Energy Saving Opportunity Scheme (ESOS), described below, is the UK's implementation of this directive.

In response to the EU's Energy Efficiency Directive, which requires all member states to establish a mandatory energy audit programme, the UK has established The Energy Savings Opportunity Scheme (ESOS). As this is only now coming into force it is too early to comment on the results, but it is notable that ESOS includes a requirement over and above those of the EU Directive, namely that the reports produced by ESOS which identify energy efficiency opportunities have to be signed off by a board member. This at least ensures that a board level manager sees the opportunities that have been identified.

United Kingdom's Energy Savings Opportunity Scheme (ESOS)

The UK's Energy Savings Opportunity Scheme (ESOS) came into effect on 17 July 2014 and requires all large organizations to identify, evaluate and report cost-effective opportunities to improve energy efficiency by 5 December 2015 and every four years thereafter. All enterprises (or group enterprises with the same parent) with over 250 employees or annual turnover more than EUR 50 million and balance sheet of EUR 43 million are required to carry out an energy assessment by the compliance date. It is estimated that up to 10,500 enterprises will have to participate. These enterprises currently consume 596 TWh of energy, representing 27% of UK's energy consumption. Approximately 35% of that is in buildings, 22% in industry and 41% in transport (Cormack 2014).

The design of ESOS was based upon the requirements of EU Energy Efficiency Directive, and advancements of standardised methods in energy management and energy auditing. It places the responsibility for compliance on two groups of people: enterprises are responsible for the overall compliance on an energy assessment – which contains an energy audit – while lead assessors are responsible for the energy audit portion of the energy assessment.

Enterprises are required to:

- Assess their business operations to confirm if they are required to comply with ESOS.
- Define the boundary of its energy assessment based on recent 12-months data and covers at least 90% of its energy consumption.
- Establish the applicable exemptions and route for compliance based on four available options: certified ISO 50001 energy management system, Display Energy Certificates (DECs), Green Deal Assessments, and energy audits.
- If 100% of the enterprises' energy consumption is not covered by a certified ISO 50001 energy management system, appoint a lead assessor to oversee the energy audits.

- Boardroom directors are required to review the findings of the energy assessment and energy audits. If the organization uses an external lead assessor, one boardroom director is required to sign off the findings. If an in-company lead assessor were used, two directors have to sign off the findings. This requirement is over and above that set by the European Directive and is considered a significant enhancement by the UK Department of Energy and Climate Change (DECC) and other observers (including the authors).
- Notify the enforcement agency on the enterprises' compliance, and retain all information as record and for future review.

In the UK, instead of retraining all energy auditors, a new level of energy auditors was created: lead assessors. Lead assessors are registered with one of several approved institutions and associations. The primary purpose of lead assessors is to review the data for energy assessment (above) and to plan, review and approve all energy audit findings.

Lead assessors are the single point of contact for all of the enterprises energy audits, including buildings processes and transport. Any energy audits are valid as long as they:

- Utilise current energy data and other data which is no older than 24 months from the commencement of each energy audit
- Contain energy consumption profiles for significant energy consuming units
- Breakdown the enterprises energy use and review how its consumption varies over time.
- Contain practicable, relevant and cost effective opportunities for improvement
- Make recommendations based on appropriate calculations which is available for inspection and where practicable, opportunities are assessed based on life cycle cost analysis (LCCA).

To support enterprises complying with ESOS, a wide range of tools and information were developed. These include:

- Letters to all enterprises and their company secretaries explaining ESOS
- Awareness seminars and workshops
- Guidance document on complying with ESOS
- Best practice guides on energy auditing
- Guidance document on implementing energy saving opportunities
- Simplified on-line reporting templates
- A Q&A helpdesk for enterprises and lead assessors.

The ESOS requirements on enterprises are associated with two other regulations in the UK: Environment Permitting Regulation and Greenhouse Gas (GHG) Reporting Regulation.

ESOS is designed to ensure:

- Top management review the identified energy savings opportunities
- The creation of one single-source set of experts to help organizations comply with regulation
- An organizational focus on gathering and analysing relevant and current energy and other data
- Public reporting of the energy assessment outcomes.

ESOS is in its first phase of implementation and therefore has not yet built up a body of experience.

An impact assessment estimated that 3.0 TWh (or 0.7%) of total national energy savings would be generated from ESOS. The first round of compliance closed on 5 December 2015 and an assessment on the effectiveness of ESOS is planned for 2016.

Until recently Australia operated a mandatory audit scheme, the Energy Efficiency Opportunity (EEO) programme.

Australia's Energy Efficiency Opportunity (EEO) programme

Australia's EEO programme commenced on 1 July 2006 requiring all large organizations to identify, evaluate and report cost-effective opportunities to improve energy efficiency. All enterprises consuming more than 0.5 PJ of energy per year were required to carry out an energy audit by the compliance date. 320 enterprises participated in EEO. Their energy consumption covers 60% of energy consumption by enterprises and approximately 40% of Australia's energy consumption.

The programme was designed to ensure the following:

- Endorsement by top management of the energy performance objective
- Involvement of experts and in-company employees with operational control of energy use
- Collection and analysis of energy data to underpin an energy assessment
- A systematic process to identify and evaluate opportunities to improve energy efficiency
- Presentation of outcomes to top management
- Public reporting of the energy assessment outcomes.

Each participating organization was required to undertake an energy assessment in line with a legislated EEO assessment framework involving seven stages. At each stage, specific notification for compliance was required. The seven stages were to:

1. Establish an EEO assessment plan that described how the key stages of EEO and its requirements will be met
2. Identify a list of stakeholders to be involved in the EEO assessments, including identification of competencies required and communication with these stakeholders
3. Collect and analyse at least 80% of the enterprises' energy consumption. This included information about policies and future plans, energy data, business activities, and data necessary to establish a high level energy-mass balance
4. Identify, through site visits and data analysis, a list of potential opportunities or improvements
5. Carry out detailed analysis on opportunities with a payback of four years or less such that business cases with a certainty of 70% were defined
6. Present business cases to top management where opportunities were assessed, and decisions for implementation recorded as either adopted, under investigation or not to be implemented
7. Continue to monitor energy consumption, any new opportunities for improvements and consequent or related decisions by top management.

To support enterprises complying with EEO, a wide range of comprehensive tools and information were developed:

- Training and seminars
- Case studies
- Industry guidelines
- Energy saving measures guide
- Assessment handbook
- Template assessment plan, government reporting, and public reporting
- Verifiers' handbook
- Website, newsletter and FAQs.

Each year, 100 to 120 enterprises were subjected to a desktop compliance check. The results were intended to contribute to the selection of companies that would undergo a full verification and site visit. They showed that, for 42% of enterprises, the priority and knowledge of energy efficiency has been raised in all levels of the organization. Around half the enterprises reported 10% savings were identified with a payback of four years of less, a further 10% of enterprises identified up to 20% savings. Nearly 75% of enterprises committed to implement the identified energy savings within the following two years (IIP 2012a).

Analysis of the EEO programme found that the total of opportunities for improvement was equivalent to 164.2 PJ, or 2.7% of Australian annual energy consumption. Opportunities with a payback of four years or less, if implemented in full, would have an annual financial benefit of AUD 1,243 million. 54% of the opportunities were implemented, giving savings of 89 PJ and financial benefit of AUD 808 million per year (Energy Efficiency Exchange 2015).

An independent evaluation of the EEO programme between 2006 and 2011 was carried out and concluded that:

- The EEO programme was effective in breaking down informational barriers and improving the identification and evaluation of energy efficiency opportunities by enterprises
- Significant improvements were made in organizational capability for energy efficiency, and in the uptake of good energy practices, particularly in the areas of data analysis, opportunity identification and decision making
- A conservative estimate is that, during the first cycle, the EEO programme was responsible for approximately 40% of energy efficiency improvements within the Australian industrial sector.

Analysis of the energy-saving opportunities reported in the EEO programme showed that the four most frequently identified categories of opportunities were: lighting (11.9%), process optimisation and controls (11.0%), heat treatment/furnaces/kilns (8.8%), and HVAC/refrigeration (8.4%) (Weiss 2009).

Despite the success of the EEO programme, it was closed from 29 June 2014 in line with the then new Australian government's commitment to reduce costs for business and as part of its deregulation agenda.

8.3.3 Mandatory energy managers

High quality energy managers are an essential part of effective energy management systems. One policy option is to mandate that enterprises above an energy usage threshold appoint an energy manager who has received an accredited level of training (training programmes were discussed in Chapter 7). India is one country that mandates enterprises to employ qualified energy managers (as well as carry out audits).

India's mandatory energy manager and energy audits

The Indian Energy Conservation Act (ECA) 2001 (amended in 2010) requires large energy intensive industries and other larger consumers (known as Designated Consumers) to have energy audits carried out by an accredited energy auditor, to designate or appoint an energy manager and to report annually on energy consumption. There are approximately 700 designated consumers in India split amongst nine energy-intensive sectors that consume energy over the defined thresholds, as follows:

- Thermal power stations over 30,000 metric tonne of oil equivalent (mtoe) per year
- Fertiliser plants over 30,000 mtoe per year
- Cement plants over 30,000 mtoe per year
- Iron and steel plants over 30,000 mtoe per year
- Chlor-alkali plants over 12,000 mtoe per year

- Aluminium plants over 7,500 mtoe per year
- Railways companies over 30,000 mtoe per year
- Textile plants over 3,000 mtoe per year
- Pulp and paper plants over 30,000 mtoe per year.

The Bureau of Energy Efficiency (BEE) provides support to these companies in implementing energy management and energy auditing by providing certified examinations for energy auditors and energy management. To become a certified energy manager, candidates should score at least 50% in three papers: general aspects of energy management and energy audit, energy efficiency in thermal utilities, and energy efficiency in electrical utilities.

Candidates who score at least 50% on the fourth paper – energy performance assessment for equipment and utility systems – are certified to be energy auditors and can function as certified energy managers. Study guides covering each of the examinations are available to registered candidates. Energy audits are also subsidised by the Indian government. At the end of every year, designated consumers are required to report energy consumption and other energy performance data.

8.3.4 Mandatory reporting

Many countries require mandatory reporting from categories of industrial users of either energy use, or carbon emissions or both. This reporting can be used to provide national (and international) data and/or to support programs to enhance energy efficiency such as fiscal measures.

An example of a mandatory reporting scheme is given by the UK's Carbon Reduction Commitment (CRC).

United Kingdom's Carbon Reduction Commitment (CRC)

In the United Kingdom the CRC Energy Efficiency Scheme is a mandatory reporting and pricing scheme to improve energy efficiency in large public and private enterprises. These are together responsible for around 10% of the UK's greenhouse gas emissions. (ESOS, described above, applies only to the private sector.) The scheme is designed to target emissions not already covered by Climate Change Agreements (CCAs) and the EU Emissions Trading System (EU ETS). It features a range of incentives to encourage enterprises to develop energy management strategies and to take up cost-effective energy efficiency opportunities. Enterprises that meet the qualification criteria of consuming over 6,000 MWh per year and use half-hourly metering must buy allowances for every tonne of carbon they emit. They therefore have to measure and report upon their emissions. The scheme is expected to reduce non-traded carbon emissions by 16 million tonnes by 2027, supporting an objective of achieving an 80% reduction in UK carbon emissions by 2050.

An evaluation by the Department of Energy and Climate Change (UK DECC 2015) of phase 1 of the scheme, which ran from April 2010 to the end of March 2014, indicates that it inspired energy efficiency investments in more than half of obligated businesses. Almost all obligated businesses were taking some form of action to address energy efficiency. More than 70% of energy managers reported that their organization's level of action on energy efficiency had increased since the scheme was introduced. The research showed that rising energy prices were the main incentive for action (80.5%), followed by an increase in board-level priority (67.4%) and a desire to improve or protect reputation (64.2%). The CRC scheme was ranked fourth, with 56% citing it as a key factor. The most common energy efficiency measures were the installation of energy efficient technologies, improved energy monitoring, energy audits and increased staff awareness through training and education.

However, from a policy design angle, many participants felt CRC imposed a significant administrative burden, especially at the beginning. It was later simplified. At the start, revenues from the scheme were recycled into rewards for companies to improve energy efficiency, perceived as a good thing, but later the government turned it into a general tax, which was either felt to be unfair or it was felt that the administrative burden should in turn have been lightened. Others thought that the process of reporting energy consumption and approving purchase of CRC allowances helped to make energy efficiency more visible within their enterprises.

8.3.5 Mandatory trading of carbon or certificates

Some jurisdictions have enacted mandatory carbon trading as a means of driving industrial energy efficiency. The European Union operates the EU Emissions Trading Scheme (EU ETS), the largest greenhouse gas trading scheme in the world, which applies to all sites with combustion plant with a total rated thermal (fuel) input greater than 20 MW. This effectively covers the main energy-intensive industries – power stations, refineries, iron and steel, cement and lime, paper, food and drink, glass, ceramics, engineering and the manufacture of vehicles, as well as large buildings such as universities and hospitals.

The EU Emissions Trading Scheme

The EU ETS uses a market-based mechanism to incentivize the reduction of greenhouse gas emissions in a cost-effective and economically efficient way (UK DECC 2013). The system operates by allocating and trading greenhouse gas emissions allowances throughout the EU – one allowance equals one tonne of carbon dioxide equivalent. In Phase III, a centralised EU-wide cap is set on the total number of allowances issued to installations in the system and this will reduce each year. A proportion of the total number of allowances is issued free of charge to installations and the remainder is auctioned. At the end of each year, installations have to make sure they have enough allowances to account for their actual emissions. They have the flexibility to buy additional allowances (on top of their allocation) or to sell any surplus allowances generated from reducing their emissions below their allocation. The buying and selling of allowances takes place on an EU-wide market. The system provides a flexible compliance system for operators, while making sure that emissions are reduced in the EU to the level of the EU cap.

Other countries, such as India, operate trading schemes with certificates, ESCerts in India and white certificates in Italy for example (Parvan 2009). The Indian trading scheme, Perform, Achieve and Trade, is described below.

India's Perform, Achieve & Trade (PAT) Scheme

The 2010 amendment of Indian Energy Conservation Act extends the mandatory duties of designated consumers to participate in the Perform Achieve Trade (PAT) cap-and-trade scheme in addition to the mandatory energy manager and energy auditor. It is modelled on similar schemes such as the US SO_2 trading programme, the Chilean offsets trading programme for suspended particulates, and EU ETS for GHGs. It is a part of the government's National Mission on Enhanced Energy Efficiency (NMEEE), one out of the eight missions under the National Action Plan on Climate Change. The scheme sets energy benchmarks and mandatory targets. Designated consumers who achieve energy savings above their targets can trade their Energy Saving Certificates (ESCerts) with those who did not achieve their targets. This provides a financial incentive to improve energy efficiency. The ESCerts can also be banked for future use.

The PAT Scheme is being implemented in three phases. The first phase covered 2012-2015 and 478 facilities from eight energy-intensive sectors: aluminium, cement, chlor-alkali, fertiliser, iron and steel, pulp and paper, textiles and thermal power plants. The energy consumption of these eight industries is approximately 60% of India's total primary energy consumption.

PAT, also administered by the Bureau of Energy Efficiency (BEE), sets the energy benchmarks for each industry sector and mandatory energy consumption targets for specific sites based on their historical consumption and a pre-determined benchmark. On average, 4.8% energy savings are to be achieved giving total savings of 6.6 mtoe in the first phase.

Any data used for baselining energy consumption and for demonstrating savings are verified by a designated energy auditor (DENA). Any company with a minimum of three certified energy auditors, with more than ten years of experience in particular designated industries, and which has conducted over three energy audits in the same industry during the previous five years, may apply to be accredited as a DENA. The trading of ESCerts between designated consumers is administered by Energy Efficiency Services Ltd (EESL). A February 2011 report estimated the total budget for design and roll-out of the scheme to be INR 3600 million (USD 57.7

million). The single largest cost – 95% of the overall budget – was the installation and maintenance of energy efficiency projects.

For any type of cap and trade scheme to function smoothly, data monitoring, baseline estimations, and regulatory framework must be strong. Trading could take place on special platforms created within power exchanges. PXIL and IEX are two power exchanges that provide platforms for the trade of ESCerts.

A comprehensive evaluation of the PAT scheme was published by PWC & the Foundation (2014) in November 2014. It praised the scheme as follows:

"The uniqueness of the scheme lies in the overall objective of improving the efficiency of the production process to achieve the ultimate target of energy savings. This approach towards energy saving is a major digression from emission reduction directives followed in several developed and developing economies which, in general, aim at reduction in absolute number of emission/(fuel) consumption units. Thus, the reduction in energy consumption once achieved through PAT will be far more realistic (pointing towards a more efficient and less energy intensive economy) than those reported through other methodologies where absolute reduction of emission units may be influenced by commercial and/or political factors."

However it also highlighted concerns about:

- adequate enforcement capability
- potential conflicts of interest on the part of assessors (lack of independence)
- lack of qualified staff, training and skills
- lack of a suitable body to fulfil the role of competent depositary of the ESCerts
- the need for staff to be employed on long-term contracts
- clarification on penalties for not supplying M&V data by deadlines.

Another review (Climate & Development Knowledge Network 2013) identified a number of key lessons:

- early buy-in from industry and other key stakeholders is essential to ease compliance
- it is essential to obtain accurate data to define coverage, establish baselines, set goals and monitor performance
- it is essential to strengthen institutional and human capacity.

8.3.6 Mandatory implementation of internationally recognised standards

Energy efficiency policy can mandate the use of internationally agreed standard on energy management and energy auditing. For example, United Kingdom's Energy Savings Opportunity Scheme (ESOS) regulation has a provision to allow the use of an ISO 50001 certified energy management system to be exempted from carrying out an energy audit. Apart from those enterprises implementing an ISO 50001 certified energy management system, ESOS requires organizations to carry out energy audits. Although no specific energy audit methodology has been singled out, the regulation and guidance make references to international standards, e.g. ISO 50002 energy audit. Policy makers can make utilisation of standards such as ISO 50001 and 50002 mandatory.

8.4 Minimum Energy Performance Standards (MEPS)

Minimum Energy Performance Standards (MEPS) can be applied to appliances, buildings, lighting and industrial equipment such as electric motors and drives. MEPS define the energy performance of equipment and prevent the sale of equipment below a set level of energy performance – essentially "choice editing" to ensure that the most inefficient products or buildings cannot be supplied.

In the industrial sector, a major area for MEPS is electric motors. They should be a target because they are estimated to consume around 35% of all electricity around the world and 70% of the electricity consumed by industry (IEA 2011a), as we saw in Chapter 4. A range of efficiency standards for motors and drives exists to help curb this level of demand.

The IEA believes that mandatory MEPS regulations "are usually the best way to ensure significant and timely market penetration of high efficiency motors". To help achieve the tremendous potential for energy savings, the IEA is encouraging its member countries to implement MEPS in line with international best practice, subject to due process and cost-effectiveness analysis – but they may do so in stages[7]. For example, Brazil launched its first regulation of the Energy Efficient Act for electric motors in 2002, which established two Energy Performance Standards for motors, a mandatory MEPS and a voluntary High Energy Performance Standard (HEPS). The standards are now compatible with those implemented in other countries.

A full range of standards for motors and other equipment can be found on the International Organization for Standardization (ISO) and International Electro-technical Commission (IEC) websites. Other equipment included on the list comprises lighting, air compressors, heating and cooling equipment (refrigeration), process controls and data centres.

Policies should encourage a) the sharing of best operating and maintenance practices amongst industries and b) the installation of energy efficient equipment during retrofitting and upgrading cycles.

[7] *A non-exhaustive list of countries with standards is to be found in: Minimum Energy Performance Standards: MEPS regulations worldwide, Siemens, March 2015, available at: http://www.industry.siemens.com/drives/global/en/motor/low-voltage-motor/efficiency-standards/Documents/meps-regulation-en.PDF*

8.5 Mandatory actions on energy suppliers and utilities

8.5.1 Utilities can have a central role in energy efficiency

Energy providers (utilities) can be pivotal in the delivery of energy efficiency improvements. Energy regulators can impose an integrated resource planning (IRP) process on utilities. This can be a powerful impetus to promote energy efficiency and other demand-side management alternatives to constructing new generation capacity. An IRP process assesses the future electric needs of the region under consideration and constructs scenarios to meet them. It is "integrated" in the sense that it looks at both demand side (conservation, energy efficiency, etc.) resources as well as the supply side (generation/power plants, transmission lines, etc.). IRPs ensure that acquired energy efficiency resources are cost-effective.

Worldwide, some energy providers are now seeing energy efficiency as a market opportunity which will help them adapt to changing market conditions. An IEA review identifies them as a logical source of financing, due to stable energy revenue cash-flows and collateral in the form of large infrastructure investments. They also have expertise in several functions that can play a role in scaling-up energy efficiency, such as tariff design, metering and billing. However, utility involvement in energy efficiency in most markets is at best embryonic.

Reshaping energy supply policy and utility regulation has great potential for accelerating energy efficiency.

In markets where energy suppliers have some form of mandate to implement energy efficiency, either through an obligation to spend a set amount or incorporate a set amount of efficiency into their portfolio, energy suppliers can build the market for energy efficiency by incorporating codes and standards into their energy efficiency efforts. Interventions by energy suppliers can help to transform the market towards increased energy efficiency.

A survey by the Institute for Electric Efficiency (2011) in the USA revealed that savings of 351 TWh were possible by 2025 under a scenario where moderate standards and codes were adopted and 556 TWh under a more stringent scenario. This represents improvements of between 8.6% and 13.6% of savings relative to a baseline forecast for the same year.

8.5.2 Demand-side management and demand-side response

Demand-side management (DSM) is aimed at modifying consumer demand for energy through various methods such as financial incentives and education. The typical primary goal is to encourage the consumer to use less energy during peak hours, shifting it to off-peak times such as nights and weekends – this is typically called demand-side response (DSR) or "load shifting". It is a short-term action, unlike improved energy efficiency which has a permanent effect. DSR contracts allow industrial and commercial customers to receive payments for voluntarily reducing demand at congested times on the electricity network. This has the knock-on effect of reducing peak demand and curbing the need for investment in new generating plants.

8.5.3 Energy efficiency investment obligations

Several countries impose some kind of energy efficiency obligations on energy suppliers, mandating a certain level of investment in energy efficiency. In Europe, energy efficiency obligations programmes in recent years have included the UK's Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP) – both of which were replaced by the Energy Company Obligation (ECO) – the Italian White Certificates programme, the French Grenelle I and II schemes, and schemes in Denmark, Flanders (Belgium), and Portugal. There is wide variation between these schemes but each one has been judged successful by its government and extended over the years.

8.5.4 The role of tariff structures

Tariff design can also help drive energy efficiency. Inclining block rates, where the per-unit price of utility consumption decreases as the energy consumption increases (typically offered only to very large consumers), can work against energy efficiency. Time-of-use rates, where the price is highest at times of peak demand, can encourage demand response and energy management.

8.6 Conclusions

Policies requiring mandatory actions from industrial enterprises, such as carrying out energy audits and appointing energy managers, can be a powerful tool for assisting enterprises to improve their energy efficiency. They should be carefully designed to be both achievable and meaningful. Compliance processes, available capacity and costs need to be considered. Introducing MEPS on industrial equipment, particularly electric motors, has proved to be successful.

Policy makers also need to consider the interactions between energy supply, utility regulations and energy efficiency. In many cases utility regulation can work against improving energy efficiency. If so, it is necessary to align the incentives for utilities' performance with overall energy efficiency policy. The use of energy efficiency obligations on utilities, which require a certain level of investment, can increase the level of investment flowing into energy efficiency. The next chapter looks specifically at the topic of financing energy efficiency investments.

Key points:

- Voluntary agreements with industry can be effective but require careful design to avoid industry pushing for Business-As-Usual targets.
- Mandatory energy performance targets can be set to reduce energy use.
- Measures that can be made mandatory include energy audits, energy managers, energy and carbon reporting and trading of energy saving certificates or carbon.
- Mandatory energy audits should include requirements to ensure that senior management see the opportunities for improved energy efficiency.
- Minimum Energy Performance Standards (MEPS) are the best way to ensure significant market penetration of high efficiency motors.
- Regulations to mandate energy efficiency programmes by utilities can be effective at increasing investment into energy efficiency.

CHAPTER 9.

Fiscal and Financial Policies

'There was some local resistance in Cornwall, where the new engines were certain to save costs in pumping out water from the tin mines, ..., the 'no cure, no pay' terms offered by Boulton and Watt – based on one third of the savings in fuel over a period of twenty-five years – saved the day.'

– Thomas Crump, The Age of Steam, p58, London, Constable and Robinson, 2007

9.1 Introduction

Although many improvements in energy efficiency can be made without investment, for example through better management of operating assets and production lines, reaching significant levels of improved energy efficiency requires funding. The business case for such investment must show that there will be financial returns, since it has to be financed.

This chapter first examines estimates of how much investment is required and then the potential sources of investment capital. These typically comprise the project host (the energy user), a third party investor or the public budget. The policy options for accelerating investment into efficiency are then reviewed. We discuss fiscal measures, the establishment of energy efficiency funds and measures to reduce investment risks such as loan guarantee schemes. Structures for using third party finance are briefly reviewed because encouraging the use of outsourced solutions and third party finance – often through Energy Services Companies (ESCOs) – can be a policy objective.

9.2 How much investment is needed?

A challenge facing policy makers everywhere is how to measure investment in energy efficiency. This is partly a problem of definition. For example, should capital expenditure on a new process that is more efficient be counted as energy efficiency capital expenditure even if it was purchased for reasons other than energy efficiency, (such as increased productivity or introducing new products)? Or do we only count investment made solely for the purpose of improving energy efficiency? There are also data collection difficulties caused by the fact that the sum total of energy efficiency investment is comprised of many small investments by various players rather than a few large and highly visible investments such as in power stations.

Nevertheless, the IEA's 2014 Energy Efficiency Market Report (IEA 2014b) estimated global expenditure on energy efficiency at between USD 310 and USD 360 billion that year. For comparison, the total investment into the energy system was estimated to be USD 1,600 billion, of which about USD 1,000 billion was in primary fuel supply (IEA 2015b). Energy efficiency spending was thus around 21% of all energy spending in 2014.

At this rate, to achieve the IEA's 450 Scenario would require increasing investment in energy efficiency to USD 1.1 trillion in 2035, with a cumulative investment by then of USD 14 trillion. This is consistent with keeping the global average temperature increase below 2°C. However, since the publication of this report, the Paris Agreement has raised the bar by aspiring to keeping the global temperature rise to 1.5°C. Consequently even higher levels of spending on energy efficiency are required. Bear in mind that it is almost always cheaper to reduce demand for energy than to increase generation capacity.

Where does the money come from? The IEA reports that about 60% of efficiency investments rely on self-financing today with most of the rest financed through loans. There is a need for a significant increase in third party financing through the deployment of financing mechanisms that help enterprises avoid the upfront capital cost with repayments made out of savings and using new sources of finance via equity markets, securitisation and, ultimately, bonds. This will require tapping into the large funds held by institutional investors such as pension funds and insurers. This would help to diminish undue reliance on the relatively short maturity loans available from commercial banks. In order to unlock this new supply of capital, governments must send dependable policy signals if they are to ensure that these investments offer a sufficiently attractive risk-adjusted return. They must also address some fundamental barriers which are discussed below.

9.3 Barriers to investing in energy efficiency

Investing in energy efficiency presents a number of challenges, along with the barriers we discussed in Chapter 5. These are acute even for third party investors or lenders who would like to increase their allocations into efficiency. The barriers described below need to be attended to by policy makers and others when they design policies and programmes to increase the rate of investment into energy efficiency.

- The small average size of energy efficiency investments (particularly compared to the needs of the institutional investors who need to invest in quanta of millions, tens of millions or even hundreds of millions of dollars/euros/pounds)
- Energy efficiency is technical in nature and therefore hard to understand for outsiders – this is made worse sometimes by an abundance of jargon and acronyms
- It is difficult to measure the outcome (unlike investment into energy supply projects which have meters attached)
- Energy efficiency investments can be seen as "boring" compared to investments in production or marketing

- As well as the savings produced being relatively invisible, the actual technology involved is also often invisible e.g. control systems
- The equipment installed can be difficult (or impossible) to recover in the event of non-payment of debt because it is embedded into a process or building.

On top of these factors, as we saw in Chapter 5, energy efficiency is rarely seen as strategic and therefore it can be neglected by management for internal capital investment.

9.4 Sources of capital

Investment capital can only fundamentally come from two sources:

- internal investment from the host organization (on balance sheet – equity or debt)
- external investment from a third party (TPI). This can come from:
- utilities, through mandated programmes
- financial investors and lenders providing equity and/or debt
- Energy Service Companies (although in practice most ESCO investment is third party finance from banks and investors)
- investment from the public sector either in the form of either commercially priced finance or some form of subsidies such as grants or low interest loans.

The scale of investment available from any host organization will be determined by the availability of funds and by capital budgeting decisions by the management, e.g. decisions about the allocation of available funds between competing projects, both offensive spending (new products, marketing, R&D etc.) and defensive (cost saving such as energy efficiency). The allocations of capital will be driven by business decisions and strategic priorities. Energy efficiency is therefore likely to have a higher priority – and therefore attract proportionally more capital – in enterprises where it is seen more as a *strategic* activity and has the strong support of senior management. This is a highlight of the research by Cooremans (see Chapter 5).

When utilities are mandated to invest in energy efficiency under their licence to operate, the ultimate source of the capital is the electricity consumers and the utility is effectively collecting a tax on consumers and spending it on efficiency. The scale of investment from utilities will be driven by the nature of any mandate they operate under. In the USA, utilities invest about USD 7 billion a year into efficiency programmes (CEE 2015). In addition to mandated programmes some utilities see developing an energy efficiency business as part of their strategy and they may invest over and above any legal mandate.

The scale of investment available from financial investors is effectively unlimited compared to the potential scale of investment needed, with the ultimate source of finance being the debt capital markets (bonds). These have access to trillions of dollars. To date, however, only a very limited number of small deals have accessed the bond market. Third party investment in efficiency of all kinds remains small compared to the potential, but it is rising. The current small size is more to do with four factors: 1) the low level of investor and lender confidence in energy efficiency as an asset class, 2) the small scale of energy efficiency investments compared to the needs of institutional investors, 3) a lack of capacity within financial institutions to understand and evaluate energy efficiency projects, coupled with 4) a lack of capacity in hosts to develop large-scale bankable projects. There are also of course fundamental limitations resulting from the credit-worthiness of the host enterprises. Banks and investors have to take a view on what level of counter-party risk they may take on.

The scale of investment available from the public sector is limited by available budgets. These are effectively set by government decisions. In recent years we have seen governments in many countries make funds available for subsidising renewable energy that are significantly larger than those made available for energy efficiency programs. These decisions have led to a major growth in renewable energy generation, even though this would not have occurred without subsidised feed-in tariffs and the fact that energy efficiency usually offers a much more attractive return compared to un-subsidised renewables. In many countries we are now seeing a move away from subsidies of any sort as part of efforts to cut national debt.

9.5 Levers for affecting the rate of investment

To increase investment flows into energy efficiency there are three basic approaches open to policy makers:

- To improve financial returns
- To reduce risks (perceived risks)
- To increase the available funds.

Financial returns can be improved by:

- Reducing capex costs (either by grants, or a fiscal measure to reduce taxes or reduce the cost of equipment)
- Removing or reforming energy price subsidies
- Reducing the financing costs, by offering low rates of interest (possibly utilising access to low cost government debt)
- Reducing transaction costs, by adopting or promoting standardised evaluation and under-writing procedures.

Risks, or perhaps perceived risks, can be reduced by:

- Mechanisms such as loan guarantees or first loss reserve funds
- Standardised development and documentation processes to reduce variability of results
- Collection and distribution of project performance data to give investors better intelligence on actual performance.

The amount of funds dedicated to energy efficiency can be increased by:

- Establishing specialised energy efficiency funds
- Aggregating a number of small projects together to provide a smaller number of high value offerings that will be more attractive to lenders
- Requiring mandatory implementation of minimum energy performance standards or the results of energy audits
- Mandating utility investment programmes
- Enabling low cost and low risk collection mechanisms e.g. Property assessed clean energy (pace) and on-bill repayment (OBR).

To support all of these it is necessary to build capacity on the demand side (energy users), the supply side (energy efficiency industry) and the financial sector. Provision of additional finance alone is insufficient. In the financial sector it is necessary to increase the level of expertise in the evaluation and underwriting processes for energy efficiency projects, which have their own special characteristics. Within the demand (energy user) and supply (energy efficiency developer and/or vendor) sides it is important to increase the level of skill in writing better, more bankable business cases. This requires learning the language of the financial sector.

We now consider these methods in turn, starting with increasing financial returns through fiscal means, grants, increasing energy prices, reducing financing costs and reducing transaction costs.

9.6 Increasing financial returns

9.6.1 Fiscal measures

Fiscal policies use the tax system to encourage investment into energy efficiency. The choice is to either increase energy prices through taxation, or to increase the benefits of investment in energy efficient equipment and systems through changes to the tax system. The latter is achieved using measures such as Enhanced Capital Allowances – which reduce corporation tax liability – reducing Value Added Tax (VAT) on energy efficient equipment, or reducing energy taxes for enterprises that invest in energy efficiency.

A range of fiscal measures are available that improve the financial returns of investing into industrial energy efficiency projects. These are:

- Tax breaks on energy efficiency investment which can be in the form of:
- Enhanced Capital Allowances
- Reduced energy taxes linked to specified investment and/or actions
- Reduced tax on energy efficiency equipment
- Energy pricing and taxes
- Grants.

These are discussed below. One approach associated with managing fiscal measures is to maintain lists of the best technologies, solutions or processes, updated by a national energy efficiency agency or similar institution. Companies purchasing equipment on the list benefit from the fiscal measure(s). The UK and several other countries use this approach.

Tax breaks on energy efficiency investment

Tax breaks on energy efficiency investment can come either in the form of Enhanced Capital Allowances which can be offset against corporation tax, reductions in energy taxes or reductions in taxes on categories of energy efficient equipment. We give examples of each below.

United Kingdom's Enhanced Capital Allowances

Enhanced Capital Allowances enable businesses to write off 100% of the cost of the new plant or machinery against the business's taxable profits in the financial year the purchase was made rather than over an extended period. The independent consultancy The Carbon Trust maintains the list of eligible technologies (the Energy Technology Product List[8]) and for a product to be on the list it must meet specific energy-saving or energy-efficient criteria.

Products covered are:

- Air-to-air heat recovery
- Automatic monitoring and targeting (AMT) equipment
- Boiler equipment
- Combined heat and power (CHP)
- Compressed air equipment
- Heat pumps
- Heating, ventilation and air conditioning (HVAC) equipment
- High speed hand air dryers
- Lighting
- Motors and drives
- Pipework insulation
- Refrigeration equipment
- Solar thermal systems
- Uninterruptible power supplies
- Warm air and radiant heaters
- Waste heat to electricity conversion equipment.

Manufacturers can apply to have their products included on the list. The energy efficiency criteria for inclusion in each product type list are made publicly available (UK DECC 2014). This provides an incentive for manufacturers to develop more efficient products, since inclusion can increase the financial return on their equipment and hence boost sales. Of course, for Enhanced Capital Allowances to be effective the company purchasing the equipment must be liable to pay corporation tax, otherwise there is no effect.

[8] *The list of products that receive Enhanced Capital Allowances is available at: https://etl.decc.gov.uk/engetl/fox/live/ETL_PUBLIC_PRODUCT_SEARCH*

The UK Enhanced Capital Allowance scheme was introduced in 2001 and an independent evaluation carried out in 2008 indicated that companies that were aware of the scheme tended to invest more in energy efficiency (HMRC & DEFRA 2008). However, the report indicated that it is difficult to disentangle the impact of other factors such as having undertaken opportunity assessments.

In practice many companies do not pay corporation tax because they utilise other tax breaks. To overcome this, an alternative approach is to reduce either energy taxes or taxes charged on the purchase of energy efficiency equipment, e.g. Value Added Tax. The Swedish programme described below is an example of the former. This also links fiscal benefits to a voluntary programme to adopt ISO 50001 and other measures, as well as offering training and other resources.

Swedish programme for Improving Energy Efficiency in Energy-Intensive Industry

The Swedish programme for Improving Energy Efficiency in Energy-Intensive Industry is an example where the fiscal measure is a waiver on energy taxes subject to the company implementing specified measures. In line with the EU's Energy Tax Directive, which sets out rules for taxing energy across the EU, an electricity consumption tax on industrial electricity of EUR 0.55 per MWh was introduced in Sweden on 1 July 2004. A programme for improving electrical efficiency in energy intensive industries was introduced on 1 January 2005 under Sweden's Energy Efficiency Act. This programme, which is a voluntary scheme, allows the waiver of the EUR 0.55 per MWh for energy intensive industries if they implement an externally certified ISO 50001 energy management system and demonstrate an electrical efficiency improvement. A company is considered to be energy intensive if it has energy costs of at least 3% of the value of the company's production or the company's energy, carbon dioxide and sulphur taxes amount to at least 0.5% of the company's added value.

Once accepted into the voluntary programme, companies commit themselves to the following activities for a five-year period:

- To implement and maintain an externally certified ISO 50001 energy management systems within the first two years.
- At the end of the first two years, to submit a report to the Swedish Energy Agency on the status of their energy management system, energy review and the list of improvement opportunities.
- In the following three years, to implement opportunities to improve energy efficiency.
- At the end of five years, to submit a report summarising the achievements.

The Swedish Energy Agency provides the following tools to support enterprises implementing an energy management system and energy reviews:

- Guides, templates and manuals
- Training courses
- Workshops and seminars to disseminate best practices
- Case studies.

The programme started in 2005 with 90 participants. The programme is currently in its third 5-year period and has 110 companies participating. Since the European Union found this programme infringes the EU state subsidy rules, no new entrants have been accepted since 2012 and the programme will be wound down in 2017. A replacement programme is currently being developed.

A total of 1,247 opportunities were identified and implemented, with an average payback of 1.5 years. The Swedish Energy Agency reports that 1.45 TWh has been saved with a financial value of EUR 43 million per year contributing towards a 15% reduction in Swedish electricity consumption.

The total electricity efficiency gained, according to the Swedish Energy Agency, is split as follows:

48% in production processes, 17% in pump systems, 7% in compressed air systems, 6% in motor systems, 4% in fans, 3% in vacuum systems, 2% in cooling systems, 3% in offices and 10% is various electricity uses.

The Swedish Energy Agency describes the following factors as contributing to its success:

- It helps businesses to focus on energy taxation as a driver to raise the profile of energy management into higher management
- The use of standardised and systematic working method provides results in both the short- and the long-term
- Suppliers are involved via procurement procedures
- Establishes a network of companies which learn from each other
- The tax reduction will result in increased profitability and reduced risks.

Reduced taxes on energy efficient equipment

One fiscal option for policy makers is to reduce taxes on the purchase of energy efficient equipment, thus reducing its capital cost and boosting financing returns. The UK operates a system of reduced Value Added Tax on domestic energy efficiency equipment such as efficient heating systems or double glazing. This has been ruled in breach of European Union rules by the European Court of Justice and therefore will be subject to change. Policy makers could potentially apply lower purchase taxes to industrial equipment such as high efficiency motors.

9.6.2 Energy prices and taxes

Low energy prices are a barrier to improving energy efficiency in all sectors, as we saw in Chapter 5. In jurisdictions where energy prices are kept artificially low by subsidies, removing the subsidies and changing to market prices will improve the attractiveness of investing in energy efficiency projects, and hence the rate of investment. However, energy price reform has many social and economic effects and these need to be carefully attended to.

Even where energy prices are not subsidised, the price of energy can be increased by taxation. The European Union's Energy Tax Directive, which came into force in 2004, established a common framework and minimum rates for taxing motor fuels, heating fuels and electricity. The Swedish programme referred to above (see box) involves reducing the tax rate for enterprises participating in the scheme.

9.6.3 Grants

One method to reduce capital costs – and hence improve financial returns of investing in energy efficiency – is to provide grants for certain types of equipment from government expenditure. An example of a grant programme is the Philippines Chiller Energy Efficiency Project. In this case projects are supported by a Clean Development Mechanism (CDM) project that produces revenues in the form of Carbon Emission Reductions (CERs). This covers the cost of the grants and programme administration.

Philippines Chiller Energy Efficiency Project

The Chiller Energy Efficiency Project is a 10-year programme supported by the World Bank and the Global Environment Facility (GEF). It utilizes the Clean Development Mechanism (CDM). It has four components:

- a grant towards chiller replacement
- measurement, monitoring and verification (MMV)
- performance standards and technical assistance
- project management.

Enterprises can choose from two financial incentives when replacing old chillers with new non-CFC based energy efficient chillers. They can either receive an up-front grant of 15% of the cost of the new chiller in return for relinquishing future carbon finance revenues (in the form of Carbon Emission Reductions, CERs) from the project, or they can receive 75–80% of the revenues that can be obtained from selling carbon emission reductions. In the second case 20–25% of the revenues from the CERs is used to cover the cost of administration, financial management reporting, marketing and other costs under the CDM.

Chile's electric motor grant is another good example of a grant scheme targeted on a key area of industrial energy use.

Chile's electric motor grants

The industrial and mining sectors account for about 38% of primary energy consumption in Chile. These sectors are heavily dependent on small motors for various tasks such as material handling and processing minerals. In 2009 Chile initiated a programme to encourage the replacement of traditional motors with high efficiency motors. With a total budget of USD 2.5 million the programme subsidised the purchase of high efficiency motors to equalise their cost with conventional units. The scheme covered motors up to 7.5 kW and in 2009 and 2010 over 5,000 motors were replaced (Center for Clean Air Policy n.d.).

Another example of a grant system, in this case administered through a utility, is South Africa's Standard Offer Model.

South Africa's Standard Offer Model

South Africa is facing an acute power crisis. There is a significant shortage of generating capacity of about 3,500 MW or about 10% of peak demand (between 6am and 1pm every weekday). Until new capacity is built, an energy demand policy targeting a reduction of electricity demand is in place. This policy is managed by Eskom, the largest state-owned utility company, which supplies approximately 95% of the electricity used in South Africa.

Eskom manages several schemes designed to target different customers and energy savings project sizes, specifically to reduce electricity demand during peak periods. This case study refers to the standard offer model – a scheme started in 2004 where the utility provider purchases verified energy demand reduction projects from its customer for a period of three years at a fixed rate.

Any Eskom customer, project developer, or energy service company (ESCO) can propose a range of electricity demand reduction projects ranging from 50 kW to 1 MW. Typical electricity demand projects are energy efficient lighting systems, building management systems, energy efficient hot water systems, process optimisation that results in electricity reduction, and the use of solar thermal systems.

Anyone wanting to apply for Eskom's standard model offer is required to perform an energy audit to identify eligible energy efficiency measures, draw up an energy monitoring and verification plan, and submit the proposal to Eskom for approval. As part of the approval process, Eskom carries out an audit of the existing facilities.

Once the proposal is approved and implemented the new installation will again be audited by Eskom and the savings verified by an independent verifier. This triggers the start of payment. The payment is a fixed 42 c/kWh (70 c/kWh for solar thermal) over a period of three years. The rates for energy savings are specified by the National Energy Regulator of South Africa (NERSA) which also channels the finance from the government. Eskom submits a budget to the government via NERSA for the standard offer projects it anticipates for the year ahead.

To support participants, Eskom maintains tools and information on its website, ranging from templates for measurement and verification, an application form, and databases of eligible technologies, accredited energy service companies and project developers.

Between its inception in October 2011 and the end of 2013, about 245 projects have been registered, realising demand savings of 118 MW and energy savings of 478.6 GWh (Webb 2013). Despite this success the programme was curtailed in late 2014 due to Eskom's financial difficulties.

As well as specific technologies grants, can be used to cover the costs of developing projects. The lack of finance, as well as technical know-how, to develop projects can be a major constraint on industrial enterprises implementing energy efficiency projects. In 2006 Chile launched a programme that provided up to 70% of the cost (up to a maximum of USD 10,000) of engaging accredited energy consultants to develop projects. Although the grant was only open to smaller enterprises – those with a turn-over of up to USD 33 million – it is a good example of using grants to overcome a specific barrier.

9.6.4 Interest rate subsidies

The financial returns of investments are improved by lower interest rates. Policies to subsidise interest rates are possible. Interest rates can be reduced either by using low cost public funds or using capital to "buy down" interest rates (ACEEE 2011b).

9.7 Risk reduction strategies

Energy efficiency investments are still considered to be risky by some investors and lenders, probably due to lack of familiarity and lack of performance data. Risks can be reduced by various mechanisms, including guarantee schemes where public authorities guarantee the returns. Another important aspect of risk reduction is the collection mechanism, how the investor or lender collects the capital repayments. Collection mechanisms such as Property Assessed Clean Energy (PACE)[9], (an addition to property taxes) and On-Bill Recovery (OBR)[10] (where repayments are added to energy bills) have been proven to be low risk collection mechanisms as end-users have to pay property taxes and energy bills.

[9] *For information on PACE see: http://www.pacenation.us*

[10] *For information on OBR see: http://www.nyserda.ny.gov/All-Programs/Programs/On-Bill-Recovery-Financing-Program/FAQ*

9.8 Increasing the amount of funds allocated to energy efficiency

As "lack of finance" has often been put forward as a barrier to energy efficiency investment one policy option is to establish specialised energy efficiency funds. Several countries have established energy efficiency funds including:

- The UK, where the Green Investment Bank has created two specialised energy efficiency funds, each with GBP 50 million investment which the fund managers had to match with external funding, resulting in two funds being established each with GBP 100 million.
- Ireland, where the government established a EUR 70 million fund comprising EUR 35 million from the government and the rest from private investors.
- Singapore, which has established a SGD 100 million fund aimed at industry.
- In Europe the EU, the EIB, Deutsche Bank and Cassa Deposita e Prestiti have established The European Energy Efficiency Fund (EEEF), a EUR 265 million fund.

Three other examples of energy efficiency funds are described below.

Argentina's Energy Efficiency Fund

The Argentinean Energy Efficiency Fund (Fondo Argentino de Eficiencia Energetica) was brought into force by the Secretaria de Energia in 2009 and aimed at industry, various sub-sectors and SMEs with funding of USD 2.18 million (World Bank 2008). It was developed under a World Bank Energy Efficiency Project.

The objective of this six-year project is to increase energy efficiency use through the promotion and sustainable growth of energy efficiency services and to reduce greenhouse gas emissions by eliminating regulatory, financing and information related barriers that limit activities and investment in energy efficiency and energy conservation.

The funds cover the development of energy audits and implementation of feasibility studies for investment in energy efficiency as well as the development of the energy efficiency fund itself.

Currently (2015) the fund provides low interest loans for energy efficiency projects in small and medium enterprises (SMEs) and is operated under the scope of the National Fund for Development of Micro-, Small- and Medium-sized companies.

Thailand's ESCO Fund

The ESCO Fund was established by Thailand's Department of Alternative Energy Development and Efficiency (DEDE) under the auspice of the Ministry of Energy. It receives grant support of THB 500 million to fund up to 50% of qualifying energy efficiency and renewable energy project and then sells Certified Carbon Reduction (CERs) credits on the international carbon market.

SMEs can apply to the ESCO fund on their own, or as part of a service offering by financial institutions, equity investors, energy service companies, and product suppliers. A minimum threshold for the energy efficiency and renewable energy projects is applicable:

- For equity investors: own financing between 10% - 50% of project, total project value has a maximum value of THB 50 Million, and has a payback between 3 and 7 years.
- For venture capitalists: own financing between 10% - 30% of registered capital, total project value has a maximum value of THB 50 Million, and has a payback between 3 and 7 years.
- For equipment suppliers: total project value has a maximum value of THB 10 Million, and has a payback of less than 5 years.
- All applications need to guarantee the energy savings and carbon savings.

Owing to the need to guarantee energy and carbon savings, the equity investors and venture capitalists normally would carry out the energy audits and feasibility studies. The cost of these studies can be included in the ESCO fund application, subject to a maximum of THB 100,000 per project. If the project is subsequently cancelled, the approved fund for energy audits and feasibility studies are to be returned to the ESCO Fund.

The Energy Conservation of Thailand Foundation and Energy for Environment Foundation act as fund managers for the ESCO fund. The fund managers are responsible for the appraisal of projects, financial due diligence, coordination with financial institutes, funds and other investors, signing contractual agreements, advice to project clients, and portfolio and risk management.

The ESCO fund is currently in its fourth 2-year phase. Phase I ran from October 2008 – September 2010, Phase II ran from October 2010 to March 2013, and Phase III ran from April 2013 to May 2015.

In each phase, THB 500 million was allocated and the fund accounts for 100% of Thailand's ESCO business.

The ESCO Fund aims to address the issue of the lack of equity capital for SMEs who develop the energy efficiency and renewable energy projects.

In Phase I, nine energy efficiency projects and six renewable projects amounting to THB 188 million were approved. Approximately 40% of funds allocated for energy efficiency and renewable energy projects in Phase 1 were deployed. Of the projects approved, 98.8% were end-user plus equipment supplier projects. Only 1.2% of projects were equity investor and venture capitalist projects.

China's Utility-Based Energy Efficiency Finance programme (CHUEE)

CHUEE was established in 2006 with the support of the International Finance Corporation (IFC) with the help of the Global Environment Facility (GEF). It has three main components:

- partial risk guarantees
- technical assistance
- market outreach through information dissemination.

The initial funding of the programme involved a USD 15 million fund from the GEF to guarantee the first loss under the loan facilities and to provide technical training. The IFC then extended guarantee facilities for over USD 215 million to three main Chinese banks: the Industrial and Commercial Bank of China (ICBC), the Shanghai Pudong Development Bank (SPDB), and the Bank of Beijing (BoB). The IFC covered 75% of the risk for the first 10% of the loss (i.e. First Loss), the remaining 25% of the First Loss was borne by the commercial banks. For the remaining 90% of any loss, the IFC covered 40% of the risk and the commercial banks the remaining 60%.

This structure mitigates the risk to the commercial banks, which is considered important especially in the early phases of what is essentially a new market for banks – energy efficiency financing.

The programme also provides technical assistance to the banks and the local ESCOs, to help the three banks become more familiar with energy efficiency finance and to introduce new products including project finance, lending to ESCOs and savings-based lending. In addition technical consultants reviewed projects on behalf of the participating banks.

Through the market outreach and dissemination activities the IFC sought to increase awareness of energy efficiency opportunities and financing options amongst target audiences of industry and banks.

As of the end of 2013 the participating banks in CHUEE had provided loans of over USD 700 million and financed 226 energy efficiency and renewable energy projects (IFC 2015).

It is also possible to work with both development and local banks to establish dedicated credit lines for energy efficiency investments.

An example of this is given by Chile where, in 2008, a new credit line was established by the Chilean Economic Development Agency with the support of the German development bank KfW. The EUR 65 million credit line is available for enterprises with a turnover of up to USD 33 million and can be used for a variety of projects. Credit is disbursed through commercial banks with a maximum of USD 1 million provided at a preferential fixed interest rate and payment terms of two to 12 years with grace periods of up to 18 months.

9.8.1 Providing finance is not the whole answer

The often-heard statement that a "lack of finance" is a barrier to increasing investment into energy efficiency does need to be unpacked and fully understood by policy makers who are designing programmes to overcome financial barriers to increased investment into energy efficiency. As we have seen, enterprises have to make choices over capital allocation. In this context, "lack of finance" really means that energy efficiency projects were allocated less capital than that required to implement all the viable (i.e. economic according to the host's criteria), identified (and possibly developed) projects proposed by the staff in charge of energy efficiency or management. When discussing external investment, for instance from financial investors or lenders, it usually means an inability to secure financing, and sometimes an inability to secure financing at an appropriate or cost-effective cost of capital.

The "lack of finance" argument put forward over many years led to a situation in some countries and market segments where the answer to the problem was seen as making specialised funds available. Some of these specialised funds, including such as those in the UK, Ireland and Singapore, have not yet been entirely successful and have experienced difficulties in deploying capital at the anticipated rate. This has been put down to a number of reasons, including: a lack of bankable projects required for external funding, the long sales cycle of externally-funded projects, and the lack of acceptance of the funded model for energy efficiency projects.

Any financial and investment policy needs to recognise that the provision of funding alone does not lead project hosts to invest. The analogy is that the availability of finance for cars does not in itself make consumers want to buy a car – people want to buy cars for a host of other reasons, a combination of both logical and emotional, the provision of finance is an enabler that allows purchasing a car but is not a driver of the fundamental demand. Successful deployment of energy efficiency funds requires considerable effort being put in to support the development of bankable, high quality projects.

9.8.2 Lack of standardisation

In 2014 the European Commission and the UNEP Finance Initiative convened the Energy Efficiency Financial Institutions Group (EEFIG). This group of about 100 members, representing financing institutions with an interest in investing in energy efficiency, was charged with writing a report on barriers to increasing the flow of private investment into energy efficiency. Their report (EEFIG 2015) concluded that lack of standardisation was a key factor affecting both the demand and supply of energy efficiency financing. Lack of standardisation in this context referred to lack of standardisation in the development and documentation of energy efficiency projects, as well as in the under-writing and contracting processes.

The Joint Research Centre of the European Commission also came to similar conclusions, highlighting:

- high transaction costs
- the difficulty of predicting savings
- the lack of standardisation.

Michael Eckhart, the head of Finance & Sustainability at Citi put it very well when he said:

- "energy efficiency projects do not yet meet the requirements of capital markets"
- "no two projects or contracts are alike"
- "Say you have 1,000 energy efficiency projects, Standard & Poor's would have to read 1,000 documents to assess the risk. Fees won't pay for that level of review".

Any policy that is designed to increase the flow of private investment into energy efficiency needs to recognise the issues identified by EEFIG and others, particularly around the lack of standardisation. Standardisation of the development and documentation process of energy efficiency projects, at least in buildings, is being addressed in North America and Europe by the Investor Confidence Project (www.eeperformance.org). This is working with the energy efficiency and financial industries to develop standardised Protocols to surmount these barriers.

9.9 Energy Service Company (ESCO) facilitation

The term Energy Service Company (ESCO) is used in different ways but is generally applied to companies that develop and implement energy efficiency projects and bring external finance to invest into projects. The investment can be direct from the ESCO but is more often from a third party. The ESCO can also provide a performance guarantee through an Energy Performance Contract (EPC). Promoting the growth of the ESCO market is often a feature of energy efficiency policies and is sometimes tied to the provision of third party capital.

Energy Service Companies and the use of third party finance

Energy Service Companies (ESCOs) can provide performance guarantees and bring third party finance for investment into energy efficiency projects. The most common form of contract used is the Energy Performance Contract (EPC), in which the ESCO develops and implements an energy saving project (often utilising several technologies in a particular site) and provides a guarantee of the savings that will be achieved.

The ESCO either provides, or, more commonly, arranges finance for the project which is usually taken onto the client's balance sheet, although off-balance sheet structures are also possible. The level of the savings guarantee is enough to ensure that the financial savings are sufficient to cover repayments of the capital. EPCs have been used primarily in the public sector rather than in industry although examples of industrial EPC projects do exist particularly for Combined Heat and Power projects.

Alternative contract forms to EPC are now being innovated, at least in the US market. These include: Managed Energy Service Agreements (MESA), Efficiency Services Agreements (ESA) and Measured Energy Efficiency Transaction Structures (MEETS). It is too early to tell how successful these innovations will be but they do appear to resolve some of the difficulties of EPCs.

Promoting the use of ESCOs and third party finance should be a part of any industrial energy efficiency policy.

9.10 International developments on energy efficiency financing

The area of energy efficiency finance is attracting a growing level of interest internationally. As well as specialised funds within countries set up by national governments the Multi-Lateral Development Banks have stepped up efforts on financing efficiency. The Asian Development Bank (ADB) in 2014 exceeded its target of investing USD 2 billion in energy efficiency and renewable energy with a total investment of USD 2.4 billion (ADB 2014). The energy saved from the energy efficiency component of this investment is estimated at 700 GWh/year of electricity and 40,347 TJ/year of fuel. In 2012 ADB invested USD 721 million, about 30% of its clean energy investment, in demand side energy efficiency (ADB 2013).

The G20 Energy Efficiency Finance Task Group has recently launched voluntary Energy Efficiency Investment Principles for G20 participating countries (UNEP FI 2015). These principles recognise the importance of energy efficiency and encourage energy efficiency investments. A number of large financial institutions have also signed up to Energy Efficiency Investment Principles, which commit them to embed energy efficiency into their operations and seek to increase investment into energy efficiency.

Green bonds, or climate bonds, are a relatively new source of finance that is becoming extremely popular within the bond market. They are bonds (long term debt instruments) that are used to finance specific environmentally beneficial measures and are issued by public bodies, banks and corporations. Proceeds are earmarked for green projects but are backed by the issuer's entire balance sheet. The investors who buy bonds are pension and insurance companies and sovereign wealth funds. There are as yet few examples of such bonds being used to promote industrial energy efficiency, and a major issue is aggregating enough projects to meet the size requirements of bond issues (which are typically in the hundreds of millions of USD), but this application is expected to increase.

9.11 Conclusions

Although industrial energy efficiency can be improved by operational measures without capital expenditure (good housekeeping), ultimately capital investment is required. Increasing the rate of investment into energy efficiency should be a prime objective and a result of policy.

Measuring that rate to the extent that it is possible can provide an overall measure of success of industrial energy efficiency programmes. Measures discussed in previous chapters such as promoting ISO 50001 or mandatory audits can increase the rate of project development but ultimately all projects have to be financed.

Finance can only come from the end-user's balance sheet or a third party (private or public finance). The availability of capital for energy efficiency from all sources needs to be increased. This can be done by increasing the financial attractiveness of the investments and addressing other barriers to investment such as the lack of standardisation and lack of expertise within the financial sector.

To increase the attractiveness of energy efficiency investments policy makers can deploy a variety of fiscal measures, tax breaks, energy prices, grants and interest rate subsidies. The perceived and actual risks of energy efficiency investments can be addressed through guarantee schemes and/or facilitating low risk collection mechanisms such as On Bill Repayment (OBR).

The amount of capital available for energy efficiency can be increased through the creation or sponsoring of specialised energy efficiency funds, but policy makers need to recognise that the provision of finance is not in itself sufficient. There is also a need to address the flow of projects standardisation of project development and documentation and fostering ESCOs.

Key points:

- Fiscal measures such as tax breaks or grants can be used to increase the attractiveness of investing in specified energy efficiency technologies.
- The risks of investing in energy efficiency projects can be offset through guarantee schemes.
- Specialised funds for energy efficiency can be established to increase the amount of capital available.
- As well as making funds available policy makers need to address the demand side for third party investment.
- Lack of standardisation of the development and documentation of energy efficiency projects is a barrier to increasing third party investment.
- The promotion of ESCOs and third party finance should be part of policies to increase investment into industrial energy efficiency.

CHAPTER 10.

Policies to Improve the Rate of Energy Efficiency Innovation

'Any new technology has to go through a 25 year adoption cycle.'

– Marc Andreesen, entrepreneur, software engineer and investor

10.1 Introduction

This chapter examines policies to improve the rate of innovation in developing solutions to increase energy efficiency in industry. It examines the stages in the innovation process, and how each stage of research, development and demonstration may be supported so that effective products reach the market place, bringing benefits to the innovator, the customer and the economy as a whole.

As we have seen in previous chapters there is a very large potential to improve energy efficiency, with cost-effective investments using existing proven technologies. Even without developing new technologies just increasing the adoption of economic, mature technologies would greatly improve industrial energy efficiency. However, technology is improving all the time and most new technologies tend to be more energy efficient than the technologies they replace, even though energy efficiency is not the driver for the development of the technology.

There is an argument for the development and implementation of policies that accelerate the development of new technologies to enhance levels of energy efficiency and/or reduce the cost of investing in energy efficiency. A country's strategic desire to develop new industries and companies may be one reason for it to encourage the research and development (R&D) of new industrial energy efficiency. Using public funds for this purpose can be justified by the fact that it creates competitive advantage for the supply side, i.e. the industry and companies producing the new technologies.

It is risky to pick winners in technology innovation, but technology development areas likely to impact on industrial energy efficiency include amongst many others: smart sensors and automation, heat recovery, new materials, and additive manufacturing.

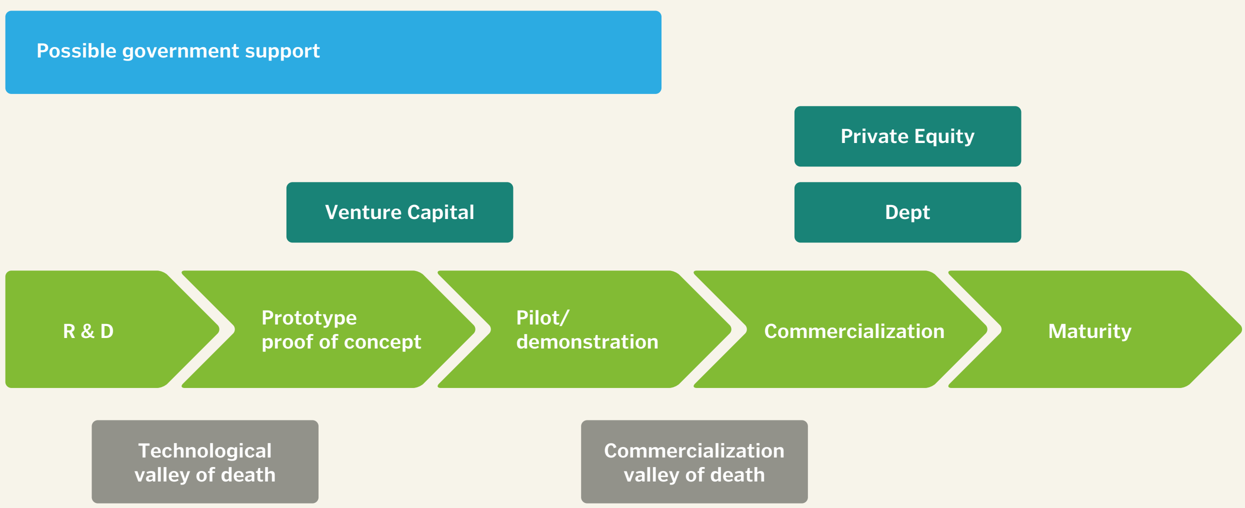
10.2 The innovation process

Any policy to promote new technology, i.e. innovation, in energy efficiency needs to fully understand the innovation process. Innovation involves many stages, from research through to incubation, demonstration, market creation, and ultimately, widespread diffusion. In practice it is evolutionary and non-linear. Outcomes are inherently uncertain. The process includes two so-called "valleys of death", the riskiest stages in the process. The first is the technological valley of death – the stage of taking a technology out of laboratory to prove its basic viability in the form of a product, essentially proof of concept. The second valley of death is the commercialisation process, as entrepreneurs seek capital to fund demonstration of first-of-a-kind commercial scale products or projects.

Figure 8 shows the stages in the innovation process and the role of different sources of finance. Government support is most often applied to the early stages of innovation, the R&D, prototype and pilot stages. Effective policies should be designed to help take innovations through these. However, care should be taken to direct resources to those innovations with the highest possibilities of success and to ensure that government support does not over-ride normal commercial and financial decision making.

Innovation is driven by technology push and demand pull. Developments in science and technology affect the generation and development of new knowledge, which opens up new commercial opportunities for innovation. Demand pull can be influenced by policies that shape the demand for innovative products and services and in particular in energy efficiency policies to address climate change are a major driver of innovation.

Figure 8. The innovation cycle and the twin valleys of death
Adapted from Jenkins et al., 2011



All innovators, whatever sector they work in, face generic barriers, especially when they are small and usually under-funded businesses. These barriers include insufficient technical resources, lack of finance and lack of marketing skills. Innovators of energy efficiency products also face barriers specific to energy efficiency. These include:

- Lack of energy management understanding within clients. In order to identify and assess proposed innovations (or to become an early adopter of new technologies), to properly evaluate them and ultimately to adopt them by implementing a project, a certain level of energy management capacity is required. This is especially true in enterprises where energy management is relegated to lower level technical staff, or in SMEs, but may be so even in larger enterprises.
- Uncertainty about savings. This barrier is related to a lack of general energy management capacity as well as lack of knowledge of Measurement and Verification (M&V) techniques. If clients perceive there to be uncertainty around energy efficiency gains they are less likely to adopt new technologies. This also applies to proven technologies.
- Conservatism in design techniques in all engineering disciplines. Most designers will tend to use a design and components they have used before. This is true across all design disciplines.
- Understandable reluctance (on the part of purchasers, either end-users or Original Equipment Manufacturers (OEMs) incorporating the technologies into products or systems) to risk adopting new technology and to place reliance on a small manufacturer for a critical part of the supply chain. Small manufacturers are unable to provide the degree of confidence that comes with a large well-known and well capitalised manufacturer or supplier.

10.3 Levels of expenditure on Research, Development and Demonstration

The interest of policy makers globally in energy innovation has sharply increased over the last decade due mainly to concerns over climate change. This is demonstrated by high levels of public expenditure on Research, Development and Demonstration (R,D&D). Amongst IEA countries public sector R,D&D spending in 2011 was USD 17.2 billion compared to about USD 10 billion (adjusted for purchasing power parity) in the mid-1990s (Rhodes et al. 2014). The proportion spent on energy efficiency has also increased over the last few years and in 2011 was USD 3.1 billion, 18% of the total. This surge in expenditure follows a twenty year slump after the end of the 1970s oil crises.

Although data on private sector investment in R,D&D is harder to obtain, it is estimated that the identifiable energy R&D spend in the 2,000 top R&D companies in 2012 was USD 21.6 billion, USD 14.1 billion of which was in OECD countries. However, 70% of the spend was associated with the oil and gas industries.

One area that has seen a significant rise in investment into energy efficiency is the venture capital market. Venture capital investments into clean energy peaked sharply in 2008 but declined following the global financial crisis but are now seeing renewed growth (Greentech Media 2013). The proportion of clean energy venture capital funding into energy efficiency appears to be increasing. There has been a number of high profile successful investments leading to either Initial Public Offerings (IPOs) or high value corporate acquisitions such as Opower's IPO and the acquisition of Nest by Google for USD 3.2 billion.

10.4 Policies to promote energy efficiency Research and Development

Tools available to policy makers to increase innovation in energy efficiency include:

- specific funding through public funds, competitions or mandated utility spending
- specialised R & D tax breaks
- fostering partnerships
- using 'champions' in industry
- the creation of specialised innovation hubs and networks.

Factors for a successful R&D policy are:

- **Consistency:** support for particular technology developments must last for years because this is the time frame which new technologies take to become commercial products.
- **Policy alignment:** the route to market must not be distorted by subsidies for energy-intensive products and services, or by measures which encourage energy use.
- **Good spread:** it is dangerous to pre-judge outcomes and attempt to cherry pick. A wide range of technologies must be backed. Less capital intensive and smaller scale technologies are more likely to prove cost-effective in the event of failure.
- **Flexibility:** institutions supporting innovation must be responsive to experience and adaptive to changing conditions.
- **Balance:** getting the balance right not only between investments in different technologies, but also between different stages of the innovation process. This includes areas where it is unlikely that a country could rely exclusively on other countries to develop the technologies it needs within the required timescales, or where it will gain most benefit from a particular technology.
- **Independence** of the innovation institutions: the ability to make decisions on funding priorities within parameters set by government: particularly important when assessing the merits of one business proposal against another and in maintaining business confidence. A refusal to bow to vested interests in choosing which concepts to support, and a refusal to "lock in" certain, perhaps already established, development routes and technical solutions at the expense of innovation and independent thinking.

Technology R, D&D programmes need to be driven with a large input from the "customer" industry in response to what it sees as its own needs.

Innovate UK

Innovate UK is the operating name of the Technology Strategy Board (TSB), the UK's innovation agency, a non-departmental public body operating at arm's length from the Government reporting to, and funded by, the Department for Business, Innovation and Skills (BIS). Its brief is to stimulate UK economic growth through innovation and much of its work is involving energy efficiency and renewable energy/ energy supply. It committed up to GBP 35 million per annum to its energy programme until 2015.

Amongst the programmes it has worked with are calls for Offshore Wind and Carbon Capture and Storage, a Marine Energy competition, and with the science Research Councils to co-fund many competitions. Competitions are held in which companies compete with bids to satisfy requests for technology development programmes to meet specific niche markets at various stages of R&D right up to pre-market stage. The organization funds the Offshore Renewable Energy Catapult Centre, catapult centres for smart metering and for smart cities. It provides test facilities and other services. It also provides policy input to Government and development of strategic partnerships. It identifies its areas for investment through a rigorous selection process involving the use of four criteria:

- Is there a large global market?
- Is the UK strong enough in both business and research to exploit the opportunities?
- Is it timely to provide support?
- Can TSB devise an intervention which will make a real difference?

Its work is complementary to that of the Energy Technologies Institute (ETI), a public/private partnership which aims to identify opportunities and develop technologies that optimise the UK's energy system for the lowest cost. The ETI's strategy is to demonstrate how the most carbon emissions could be saved at least cost. The TSB's is to decide whether to support a business with high growth potential from a new technology with global markets. The ETI supports technology development and innovation providing energy system cost benefits to the UK in the wider context of delivering the UK's energy and climate change targets. Both bodies recognise that there needs to be careful co-ordination of their respective programmes to prevent overlap and duplication.

The need for policy coordination is demonstrated by independent evaluations of British government efforts to support renewables and energy efficiency to determine whether they delivered value for money. In 2010, the British National Audit Office reported a legacy of poor coordination of a wide range of direct support for development of renewable energy/energy efficiency technologies from across government departments and other public funding agencies. The office reported that the Government had no coherent delivery framework, nor a consistent approach to evaluation and reporting on the results from public funding. Without this it was not possible to demonstrate whether value for money from public funding was being achieved. As a result, The UK Low Carbon Innovation Co-ordination Group was re-launched with a broader remit and produced ten Technology Innovation Needs Assessments which provided analysis to determine the case for public support for innovation. The UK's National Audit Office has also conducted a triennial assessment of the TSB. TSB has also itself invested in evaluations to measure the impact of its programmes which showed that its collaborative support achieved a return of GBP 6.71 per project pound invested. Larger multiples have been identified in some of its innovation platforms.

Another form of innovation programme, which took a systematic view of the need to develop and implement low carbon technologies in electricity distribution and end-use, is the UK's Low Carbon Network (LCN) programme. This is run by the regulator, OFGEM. The LCN programme was focused on the demonstration stage of innovation and in particular integrating a range of technologies into effective solutions. It brought together large companies, the Distribution Network Operators and others, with small innovative companies who would have had great difficulties in demonstrating their technologies at scale without support from the programme.

United Kingdom's OFGEM Low Carbon Network

The Low Carbon Networks (LCN) Fund in the UK was a recent scheme that supported innovation in new low carbon technology. As part of an electricity distribution price control mechanism that ran until 31 March 2015, OFGEM, the UK energy regulator, used the Fund to provide up to GBP 500m to support projects sponsored by the Distribution Network Operators (DNOs) to try out new technology, operating and commercial arrangements.

There were two tiers of funding. The First Tier allowed DNOs to recover a proportion of expenditure incurred on small scale projects. Under the Second Tier, OFGEM ran an annual competition for a grant of up to GBP 64 million to help fund a small number of flagship projects. DNOs used the funds to explore how networks can facilitate the take up of low carbon and energy saving initiatives such as electric vehicles, heat pumps, micro- and local-generation and demand-side management. They also investigated the opportunities that smart meter roll-out provides to network companies.

10.5 Conclusions

Even though improving industrial energy efficiency does not require any new technologies there is an argument for also supporting research, development and innovation in energy efficiency technologies. This can help to achieve higher levels of energy efficiency in future and to build new industrial capability in a growing market. Encouraging innovation in energy efficiency is likely to be a part of a wider innovation programme. Many of the issues faced are similar to those generally in technology innovation. The importance of the energy network, and the scale of investment needed, bring with them extra dimensions of difficulty. These need to be addressed by any programme.

Key points:

- Although most effort should be focused on the application of economic, mature technologies there are arguments to support innovation in energy efficiency technology.
- Public and private expenditure on energy efficiency innovation is increasing globally.
- Innovation programmes should be long-term and consistent.
- R&D programmes need to be driven by input from the customer industries.
- Government support can be used to help bridge the twin valleys of death but care must be taken to ensure that innovations are really aimed at meeting real customer needs.
- A wide spread of technologies is needed as the failure rate is high.

Photo: Calvin Teo

CHAPTER 11.

Integrated Examples and Conclusions

'A system is a whole that cannot be divided into independent parts or subgroups of parts'

– Russell Ackoff, pioneer of systems thinking, 1919 - 2009

11.1 Introduction

This chapter stresses the need for integrated policies that draw upon the types of measures described in the preceding chapters. It presents some examples of integrated industrial energy efficiency policies and then draws some final conclusions.

11.2 Integrated examples

The book has tried to set out both principles and options for policy makers charged with improving industrial energy efficiency. It has examined policies in four areas: Information-led and capacity building, Institutional, regulatory and legal, fiscal and financial, and technology innovation. These have been separated out in the text, but the reality is that effective policies to promote industrial energy efficiency draw upon most, if not all, of these approaches. For instance, individual programmes may draw upon information and capacity-building and fiscal and financial measures.

Before making some final conclusions we present some examples of wide-ranging policies that draw together the types of measures we have outlined in the previous chapters. They come from India, Malaysia, Vietnam and the Philippines.

India and the Berkeley-India Joint Leadership on Energy and the Environment

India currently ranks fourth in the world in terms of primary energy demand and fifth when biomass is excluded. It aims to achieve 8-10% of GDP growth per annum through to 2030, therefore at the current rate, its primary energy supply will need to grow by up to four times and electricity supply by up to seven times. But an analysis of its electricity efficiency potential has shown that efficiency improvement in combination with new supply can eliminate electricity shortages at the same investment level as for a business-as-usual electricity supply, and that higher penetration of energy efficiency technologies reduces the need to construct more power plants, thereby reducing fuel imports and India's CO_2 emissions by 300 Mt CO_2/year by 2017 (Sayathe et al. 2010).

Industrial energy intensity increased until the mid-1980s and continually declined after that. This is similar to the trend in the US and China, although the decline in India was not as steep as that in China. There, concerted policies and programmes in the industrial sector led to a dramatic decline beginning in the 1980s. Market barriers to improving efficiency in Indian industry include: lack of incentives, lack of understanding, lack of ESCOs, lack of financial help from banks and other lenders, and a failure by the power sector to treat energy efficiency on the same economic basis as new capacity, meaning that there is a great need for demand side management programmes (Sayathe 2012).

In this context, the Berkeley-India Joint Leadership on Energy and the Environment (BIJLEE) was a partnership between the University of California, Berkeley (UCB), the Lawrence Berkeley National Laboratory (LBNL) and the government, private sector and educational institutions of the USA and India. The partnership ran from 2008 to 2012 to help both countries adopt pathways and approaches for reducing the emissions of greenhouse gases (GHGs) while pursuing sustainable economic development. It had three documented outcomes:

- **Clean Energy Options for India:** Researchers analysed the financial and emissions impact of clean energy options like grid-connected renewable energy and energy efficiency programmes for India. They contributed to the formulation of demand-side management regulations in several state electricity regulatory commissions. They provided technical assistance, along with the Prayas Energy Group, on the conceptual design of an upstream DSM incentive programme for promoting super-efficient appliances. They helped to estimate the total potential of efficiency enhancement in India and its impact on utility finances and consumer tariffs.

- **Data Centre Energy Efficiency Initiative:** it worked with the Indian government and industry to develop and expand a national initiative to improve energy performance in data centres (now growing at 30%/year according to the Confederation of Indian Industry), and published guidelines for data centre energy information systems (Singh 2013).

- **Industrial Energy Use and Economic Analysis:** This primarily focused on economic modelling of energy use in up to ten key energy-intensive industries such as iron and steel and cement, collected by selected unit processes and technologies. Models were used to estimate cost-effectiveness and carbon benefits of energy-efficiency options to provide a basis for projecting low carbon futures and setting efficiency policies.

GMR was one company that took part in this project, where best energy efficiency practices were captured and shared with other plants for implementation. It identified 18 energy conservation projects out of 36 as having a saving potential of Rs.48.7 million and prioritised them for implementation. These included the optimisation of operations involving cooling tower fans, cooling water pumps, direct bunkering, jockey pumps, variable frequency drive installation for liquid fuel pumps, energy audits, energy conservation awareness programmes, etc. At one such plant, four projects resulted in energy savings of 3,205 MWh/annum. Offices have also been designed for maximum utilisation of natural light and provided with occupancy sensors for lighting (GMR 2015).

Malaysia

Malaysia took its first steps on energy efficiency policy in 1999. The Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) ran up to 2007 with support and funding from the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) as well as the Government of Malaysia and the private sector. It focussed on eight energy-intensive industries: wood, rubber, food, ceramics, glass, pulp & paper, iron & steel and cement, with three other sub-sectors added later: plastics, textile and oleo-chemical. It used voluntary participation and the following tools:

- Establishment and publication of (sub-sectoral) energy benchmarks: a database of more than 1,500 industries built up from data from the Department of Statistics (DOS), although some limitations were found with this process.
- Energy auditing of 54 industries in the sub-sectors: cement (3), ceramic (6), iron & steel (4), food (10), glass (3), pulp & paper (6), rubber (9), wood (7), oleo-chemical (2), plastics (2) and textile (2) and the publication of a 56-page document called "Industrial Energy Audit Guidelines – A Handbook for Energy Auditors".
- Energy rating programmes for energy-efficient equipment: an energy-efficient motor rating and labelling programme was proposed to the Energy Commission, but only implemented on a voluntary basis so far at the time of the project evaluation in 2007.
- Widely disseminated information on energy-efficient processes, technologies and practices: a 'Boiler Best Practice' guidebook, plus numerous workshops and seminars, and the establishment of the MEPA, an association of energy experts, open to energy practitioners of various academic backgrounds. A booklet "Achieving Industrial Energy Efficiency in Malaysia" was published by UNDP.
- Training and support for local energy service companies (ESCOs): a Master Energy Services Agreement (MESA) was drawn up by the MIEEIP Team at PTM as a sample document to assist ESCOs and industries in the implementation of energy efficiency activities, but despite training and seminars, the ESCO industry in Malaysia did not develop well.

- Demonstration projects of significant energy efficient technology and processes: ten were established in energy-intensive industries: pulp and paper, glass, food, steel, palm oil, and three involving local equipment manufacturers: motor rewinding, fans, by means of feasibility studies and investment support through the Energy Efficiency Projects Lending Scheme, EEPLS. One demonstration project (Heveaboard Bhd in Gemas) based on the ESCO concept was successfully implemented.

The project made important contributions to removing some barriers, in particular raising energy efficiency awareness and capacity in areas such as benchmarking, best practices, audits and demonstration. It represented a first step for a country getting used to the ideas, in creating basic skills to understand the factors affecting decision-making concerning energy efficiency by industrial energy users as well as consultancy companies. It generated powerful insights into the technical and economic potential for energy efficiency initiatives and the means available to government to realise that potential. Any longer-term benefit could not continue without further continuous government support and legislative and financial interventions.

Subsequent evaluation found that the lack of a consistent policy and planning framework in Malaysia for energy efficiency was the biggest barrier, and that the project lacked a component on energy efficiency planning and regulations. Another main barrier was the highly subsidised energy prices in the country. Recommendations included reducing energy subsidies and introducing better tax incentives, 'energy management regulations' for high energy using companies, better use of energy standards and labelling, and the wider use of E-Benchmarking tools.

Despite the low cost of energy, the MIEEIP project managed to demonstrate the feasibility and achievability of energy saving measures and enticed managers in industrial companies as well as some financial institutions to get involved in energy efficiency and conservation.

Vietnam – Vietnamese Energy Efficiency and Conservation Program (VNEEP)

Energy use in Vietnam is growing rapidly due to its fast-growing economy. 18% of energy use is accounted for by industry, split 10% in light industry and 8% in heavy industry. The Vietnamese Energy Efficiency and Conservation Program (VNEEP) is a ten-year programme, beginning in April 2006. It was the first-ever national comprehensive plan to institute measures for improving energy efficiency and conservation across all sectors of the economy. The overall aim was to make initial savings of 3-5% during the period 2006 - 2010 and a further 5-8% during the period 2011 – 2015. Within industry the specific target was to save between 875 and 1,400 ktoe by the end of 2015.

VNEEP specified six components and eleven projects to achieve these savings.

The Energy Efficiency and Conservation (EEC) Office of the Ministry of Industry and Trade (MOIT) took the leading role in implementation, collaborating with specialised institutions such as the Energy Institute, Energy Conservation Centres and universities. Within industry VNEEP aimed to undertake energy audits in 300 large enterprises and 12 power plants, have 1,024 designated enterprises with an energy management system (EnMS), and certify 2,500 energy managers and 200 auditors.

On 1 January 2011 the Law on Energy Saving and Efficiency (No.50/2010/QH12) came into force, which included sections establishing mandatory energy labels and mandatory efficiency standards for appliances, equipment, technology and products. It also set energy efficiency requirements into building codes and required utilities to offer energy efficiency plans.

To date the programme has established energy management systems in 250 designated enterprises and certified 350 energy managers and 60 energy auditors. Energy audits have been carried out in more than 240 enterprises with energy efficiency measures implemented in 50 enterprises. The total energy saving (across all sectors) is estimated at 4,900 ktoe, corresponding to 3.4% of energy usage for the participating enterprises.

The Philippines

The Philippines has a long history of developing and implementing energy efficiency policies and programmes. A Technology Transfer for Energy Management Programme began in 1985 and provided energy audits, technical assistance and below market loans to over 120 companies to help them adopt energy saving technologies. It was funded by USD 4.6 million from the US Agency for International Development. A Demonstration Loan Fund was used to show off technologies and practices not widely used in the country. Nearly 1,100 participants from both the public and private sectors attended 25 nationwide seminars. 16 projects were completed. They showed an average internal rate of return of 41% with very significant cost and pollution savings.

Since then, progress has stalled until recently. The Department of Energy and of Science and Technology (DOST), in collaboration with a number of government and private enterprises like the Philippines Appliance Industry Association, is implementing a standards and labelling programme for households and commercial sectors. This programme is currently being implemented on voluntary basis. It has already developed and implemented standards for refrigerators and air-conditioners, and is expected to include television in the near future.

The industry sector, whose energy demand is largely met by coal, consumes about one-quarter of the national total. Demand is projected to grow at about 3% per year from 2010 to 2035 without intervention. The Philippines government, supported by UNIDO, recently launched The Industrial Energy Efficiency Project, which seeks to improve industrial energy efficiency through the provision of tools and capacity-building. Most of the industrial sector is based on processing and assembly operations in the manufacturing of textiles, paper and paper products, electronics and other high-tech components. Heavier industries are dominated by the production of cement, glass and glass products, industrial chemicals, fertilisers, iron and steel, fabricated metal products, mineral products, machinery and equipment, transport equipment, and refined petroleum products.

Under the project, the government has drawn up an Energy Efficiency and Conservation Roadmap 2012-2030 and the Energy Efficiency and Conservation Bill 2014. This will be the first national policy or regulatory instrument to enforce energy efficiency. Some of the activities include:

- Capacity building, supported by IIEE and The Energy Efficiency Practitioners Association of the Philippines (ENPAP) through training in the implementation of ISO 50001.
- A GEF-funded Philippines Chiller Energy Efficiency Programme, being implemented by the Department of Environment and Natural Resources, which aims to replace inefficient CFC-based chillers with new and efficient non-CFC chillers.
- The High Energy Efficiency Motors (HEM) Programme of the EU's SWITCH-Asia Programme, being implemented by a consortium consisting of the Institute of Integrated Electrical Engineers (IIEE), the International Copper Association (ICA) and the Asia Society for Social Improvement and Sustainable Transformation (ASSIST). This promotes high-efficiency motors and drive systems in the sugar industry and demonstrates that investment makes a good business case, with a typical payback of less than one year.
- The ASEAN Standards Harmonisation Initiative for Energy Efficiency (ASEAN SHINE) to harmonise standards in ASEAN countries, including the Philippines, as well as encouraging the development of national policy roadmaps, being implemented by The International Copper Association (ICA), the Philippine Chamber of Commerce and Industry (PCCI) and the Department of Trade and Industry (DOTI).
- Work with electrical utilities to improve the energy performance of distribution transformers, led by the ICA.
- Work to connect investors and clean energy businesses, including with reference to energy efficiency, led by The Climate Technology Initiative: Private Financing Advisory Network (CTI-PFAN). This has supported sugar mill industries in accessing finance to implement energy efficiency.
- Training of electricians to educate them on using energy efficient products during electrical installation, retrofitting and replacements in all sectors.

The Department of Energy is also actively promoting energy efficiency in the country through various programmes, e.g. reduction of energy consumption in government buildings and operations by 10% annually.

However, barriers still remain (Copenhagen Centre on Energy Efficiency 2015). These include:

- A relatively weak regulatory framework
- A need to develop a systematic monitoring and verification (m&v) mechanism
- A need to demonstrate new and advanced technologies
- An absence of an appropriate institutional mechanism to provide long-term support for energy efficiency implementation
- A lack of financial support to offset high capital investment for smaller companies to undertake energy efficiency measures
- A lack of quality testing infrastructure to implement standards and labelling programmes effectively.

11.3 Conclusions

Exploiting the energy efficiency resource by improving industrial energy efficiency is a rational response for all countries to energy-related problems. Such problems include the need to improve energy security and to reduce environmental impacts at local and global levels. The benefits of improved energy efficiency accrue to everyone: the enterprises making the improvement, to the energy supply system, and to the economy as a whole. As well as energy related benefits such as reduced energy costs and reduced exposure to energy price volatility, improved efficiency can bring many other non-energy benefits such as improved productivity, increased employee engagement, job creation and improved health and well-being, with fewer health costs.

The technologies to improve industrial energy efficiency in all sectors are well known, mature and well proven. There is no need to develop new technologies to significantly improve industrial energy efficiency. Simply spreading the adoption of the existing and economically viable technologies and bringing all enterprises closer to Best Available Technology or even current average energy performance would result in energy savings in most sectors in most countries. The systems and tools of energy management are well known. Improving the capacity for energy management within enterprises will result in improved efficiency across all sectors.

The numerous energy and non-energy benefits of improving industrial energy efficiency, coupled with an assessment of global, regional and national energy scenarios for the next 20 to 30 years, should make improving energy efficiency a higher, national strategic priority in all countries.

Policy makers charged with improved industrial energy efficiency have a number of options available to them for policy and programme design and a wide range of examples to draw inspiration and learning from, a small selection of which are included in this book. They also have a number of sources for assistance, described in the next section. Targeted policies across key industrial sectors will help accelerate improvements in the industrial energy efficiency and deliver larger impacts and benefits. Policies should use a blend of information and capacity building programmes, institutional, regulatory and legal measures, and fiscal and financial measures.

Besides pursuing the strategies described in this book, governments can play an essential role in integrating the value chain for energy efficiency technology suppliers. They may act as guarantors and facilitate proper accreditation and certification standards, and publish independently verifiable, accurate information about energy efficiency technologies, suppliers and ESCOs. The value chain does not just cover technology supply, but also training, support, maintenance and operation. To develop these markets, which will support improvements in industrial energy efficiency, governments should also lead by example and launch demonstration projects and procurement policies in line with best practice within their own estate.

Implementing new, comprehensive and well-targeted policies to improve industrial energy efficiency, and strengthening existing policies, will produce significant economic and environmental benefits for all countries. Action to increase industrial energy efficiency should be a core component of the world's efforts to keep the average global temperature increase to 1.5 degrees Centigrade above pre-industrial levels.

Sources of Assistance

Policy makers seeking further assistance can consult several sources both to develop and implement industrial energy efficiency policies. The following is only a partial list. Assistance is also available from multi-lateral banks and many other institutions.

- The **Global Energy Efficiency Accelerator Platform** is a key initiative of the Sustainable Energy for All's (SE4All) to help double the global rate of energy efficiency improvement by 2030. One of the sectoral-based accelerators is focused on accelerating energy efficiency in the industrial sector and is being led by UNIDO and a number of other partners.

- **United Nations Industrial Development Organization (UNIDO)** runs programmes in developing and emerging economies to develop capacity and transfer technology.

- **The International Energy Agency (IEA).** The IEA is an autonomous organization which works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA has four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide. The IEA International Low Carbon Energy Technology Platform is the IEA's chief tool for multilateral engagement on clean technologies between its member and partner countries, the business community and other international organizations.

- **The Institute for Industrial Productivity (IIP).** IIP is an independent non-profit organization whose role is to accelerate the uptake of industrial energy efficiency practices by partnering with both industry and governments

- **The Collaborative Labelling and Appliance Standards Programme (CLASP)** identifies and responds to the needs of standards and Labelling practitioners in targeted countries and regions while making available globally high quality technical information on best practice in standards and Labelling. It collaborates with policy makers and members of industry alike at local, regional, and international levels, to promote the improved energy efficiency of appliances, lighting, and equipment, significant reductions in electricity consumption, and abatement of greenhouse gas emissions.

- **The International Partnership for Energy Efficiency Cooperation (IPEEC)** is an autonomous intergovernmental entity. Currently, IPEEC members include Australia, Brazil, Canada, China, the European Union, France, Germany, India, Italy, Japan, Mexico, the Russian Federation, South Africa, South Korea, the United Kingdom, and the United States. Other countries, non-governmental organizations, international organizations and private sector entities actively participate in IPEEC's Programme.

- **Clean Energy Ministerial (CEM)** is a global forum to share best practices and promote policies and programmes that encourage and facilitate the transition to a global clean energy economy.

- **Global Environment Facility (GEF)** was established on the eve of the 1992 Rio Earth Summit, to help tackle our planet's most pressing environmental problems. Since then, the GEF has provided USD 14.5 billion in grants and mobilised USD 75 billion in additional financing for almost 4,000 projects. The GEF has become an international partnership of 183 countries, international institutions, civil society organizations, and private sector to address global environmental issues.

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Abbreviations

A	Ampere – unit of electrical current
ACEEE	American Council for an Energy-Efficient Economy
AChEE	Chilean Agency for Energy Efficiency
ADB	Asian Development Bank
AEE	Association of Energy Engineers
AMR	Automated Meter Reading
ANAB	ANSI-ASQ National Accreditation Board
ANSI	American National Standards Institute
ASEAN	Association of South East Asian Nations
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BACT	Best Available Control Technology (US equivalent to BAT)
BAT	Best Available Technique (or Technology)
BATNEEC	Best Available Technique Not Entailing Excessive Costs
BEE	Bureau of Energy Efficiency (Indian energy efficiency agency)
BMS	Building Energy Management System
BOE	Barrels Oil Equivalent
BTU	British Thermal Unit
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CEM	Clean Energy Ministerial
CEMEP	European Committee of Manufacturers of Electrical Machines and Power Electronics
CER	Certified Carbon Emission Reduction Credit
CERT	Carbon Emissions Reduction Target – mandatory energy efficiency supplier obligation for UK utilities 2008 to 2011
CESP	Community Energy Saving Programme – mandatory energy efficiency supplier obligation for UK utilities 2009 to 2012
CHP	Combined Heat and Power
CHUEE	China Utility-Based Energy Efficiency Finance programme
CIBSE	Chartered Institution of Building Services Engineers (UK engineering body)
CO_2	Carbon dioxide
CONUEE	National Commission for the Efficient Use of Energy (Mexico)
COP	Coefficient of Performance – usually applied to heat pumps
CSR	Corporate Social Responsibility
D3	Shorthand for Demand Management (DM), Demand Response (DR) and Distributed Generation (DG)
DCF	Discounted Cash Flow
DECC	Department of Energy & Climate Change (UK government department)
DEDE	Department of Alternative Energy Development and Efficiency (Thai energy efficiency agency under Ministry of Energy)
DG	Distributed Generation
DH	District Heating
DNO	Distribution Network Operator (UK term for electricity network operator)
DM	Demand Management (permanent reduction of load through energy efficiency)
DR	Demand Response (short-term reduction in load or time shifting of load)
DSM	Demand Side Management (utility programme aimed at reducing demand)
DSR	Demand Side Response (same as DR)
EBRD	European Bank of Reconstruction and Development
ECA	Enhanced Capital Allowances
ECLAC	Economic Commission for Latin America and the Caribbean
ECM	Electrically Commutated Motor
ECO	Energy Company Obligation – UK scheme to mandate spending on energy efficiency by energy suppliers 2013 to present
EEEF	European Energy Efficiency Fund
EEFIG	Energy Efficiency Financial Institutions Group (group established by the European Commission and UNEP Finance Initiative to report on how to increase the flow of investment into energy efficiency)
E-FiT	Energy efficiency Feed-in Tariff
EISA	Energy Independence and Security Act of 2007 (US law)
EJ	Exajoule (unit of energy – 10^{18} joules)
EnMS	Energy Management System (a management system as opposed to an electronic control system such as a BMS)
EPA	Environmental Protection Agency (US)
EPAct	US Energy Policy Act
EPC	Energy Performance Contract
ESA	Energy Services Agreement (similar to MESA)
ESKOM	South African utility
ESCO	Energy Service Company
ESPC	Energy Saving Performance Contract

EU.ESCO	European Association of Energy Service Companies
EVO	International not-for-profit providing IPMVP
FiT	Feed-in Tariff
GCV	Gross Calorific Value
GEF	Global Environment Facility
GHG	Greenhouse Gases
GSEP	Global Superior Energy Performance (global extension of SEP)
GSHP	Ground Source Heat Pump
GWP	Global Warming Potential
HEPS	High Efficiency Performance Standard (Brazilian voluntary motor standard)
HTS	High Temperature Superconductivity
HVAC	Heating, Ventilation and Air Conditioning
ICP	Investor Confidence Project
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IFI	International Financial Institution
IGA	Investment Grade Audit
IOU	Investor owned utility (USA)
IP	Intellectual Property
IPEEC	International Partnership for Energy Efficiency Cooperation
IPMVP	International Performance & Measurement Protocol
IPO	Initial Public Offering
IPPC	Integrated Pollution Prevention and Control Directive (EU Directive adopted in 1996)
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Planning (for utilities)
IRR	Internal Rate of Return
ISO 50001	International Standard 50001 Energy Management
J	Joule (unit of energy)
KEMCO	Korean Energy Management Company
KfW	German development bank
KPI	Key Performance Indicator
kW	Kilowatt – unit of power
kWh	Kilowatt hour – unit of energy
LAS	League of Arab States
LBL	Lawrence Berkeley National Laboratory – US Department of Energy national laboratory
LED	Light Emitting Diode
LEEF	London Energy Efficiency Fund
LNG	Liquefied Natural Gas
M&T	Monitoring and Targeting
M&V	Measurement and Verification
MACC	Marginal Abatement Cost Curve
mCHP	Micro-Combined Heat and Power
MEPS	Minimum Energy Performance Standard
MESA	Managed Energy Services Agreement
MIEEIP	The Malaysian Industrial Energy Efficiency Improvement Project
MJ	Megajoule (unit of energy – 1,000,000 joules)
mtce	Million tonnes coal equivalent
mtoe	Million tonnes oil equivalent
MW	Megawatt – unit of power
MWh	Megawatt hour – unit of energy
NEMA	National Association of Electrical Manufacturers (US trade association0
NERSA	National Energy Regulator South Africa
NMEEE	National Mission on Enhanced Energy Efficiency (India)
NPI	Normalized Performance Indicator
NO_x	Oxides of nitrogen
NPV	Net Present Value
OBR	On Bill Repayment
OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OFGEM	Office of Gas and Electricity Markets (UK regulator of gas and energy supply industries)
OLADE	Latin American Energy Organization
ORC	Organic Rankine Cycle
PACE	Property Assessed Clean Energy
PDCA	Plan, Do, Check, Act (as used in ISO 50001)
PJ	Petajoule – unit of energy – 10^{15} Joules
ppm	Parts Per Million
PRMS	Petroleum Resource Management System
QBTU	Quadrillion British Thermal Units
R & D	Research & Development
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
R, D & D	Research, Development and Demonstration
RDF	Residue (or Refuse) Derived Fuel
RMI	Rocky Mountain Institute
RTG	Radio-isotope Thermal Generator
SAAS	Software as a service
SEAI	Sustainable Energy Agency of Ireland
SEC	Specific Energy Consumption
SEP	Superior Energy Performance (programme of US Department of Energy)
SME	Small & Medium Enterprise
SOFC	Solid Oxide Fuel Cell
SO_x	Oxides of sulphur
SRF	Solid Recovered Fuel
TPI	Third Party Investment
TWh	Terawatt hour
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework on Climate Change

USAID	United States Agency for International Development
V	Volt – unit of electric potential, difference in electric potential or electro-magnetic force
VAT	Value Added Tax
VNEEP	Vietnam Energy Efficiency and Conservation Program
VRLA	Valve Regulated Lead Acid batteries
W	Watt – unit of power
WBCSD	World Business Council for Sustainable Development
WEO	World Energy Outlook (series of scenarios and reports produced by the IEA)
WHO	World Health Organization
WHP	Waste Heat to Power

A note on energy units

One of the realities of studying energy is that there are many different units for measuring energy. There are both metric and imperial units, with specific units for different types of energy driven by local or regional historical usage. Any energy professional has to become used to converting from one unit of energy (and power) to another. In this book we have avoided converting units from the original works cited. Common units of energy used at the macro, national or international level are:

BCF – Billion cubic feet of gas
BCM – Billion cubic meters of gas
BOE – Barrels of oil equivalent
EJ – Exajoules (10^{18} joules)
GWh – gigawatt hours
ktoe – thousand tonnes oil equivalent
kWh – kilowatt hours
GWh – gigawatt hours
Mtoe – million tonnes oil equivalent
MWh – megawatt hours
QBTU – quadrillion British Thermal Units (‘Quad’)
TWh – terawatt hours

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Governments at various levels are striving to make their production systems more sustainable and competitive. Improving energy efficiency of industry has proven to be successful and cost-effective while delivering multiple benefits. This book describes industrial energy efficiency, highlighting the technology options, decision-making processes and barriers to energy efficiency investments. Policy options to improve industrial energy efficiency are presented, which are supported by concrete case studies showing their application. While the focus is on energy intensive industries, many of the approaches described can also be applied to other industrial and commercial sectors as well as small and medium enterprises.

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