2. Improving energy efficiency in organisations

2.1 Introduction

The aim of this chapter is to evaluate the importance of energy efficiency improvement in organisations and to introduce the notion of the 'energy efficiency gap' (i.e. the gap between actual and optimal energy use in organisations). This chapter will begin by describing the urgent energy supply transition that is currently underway. This transition, driven by the rising concentration of greenhouse gas emissions in the atmosphere, involves a shift away from society's reliance on fossil fuels and a shift towards the development of low carbon energy systems. The multiple benefits that accrue from improved energy efficiency (i.e. using less energy to deliver more goods and services) are then examined. This highlights the significant potential that improved energy efficiency performance in organisations can deliver to organisations and society more broadly. Finally, the notion of the energy efficiency gap (defined above) is introduced. The chapter establishes the wider environmental, social and economic context within which this thesis research is conducted.

2.2 The transition to a low carbon energy system

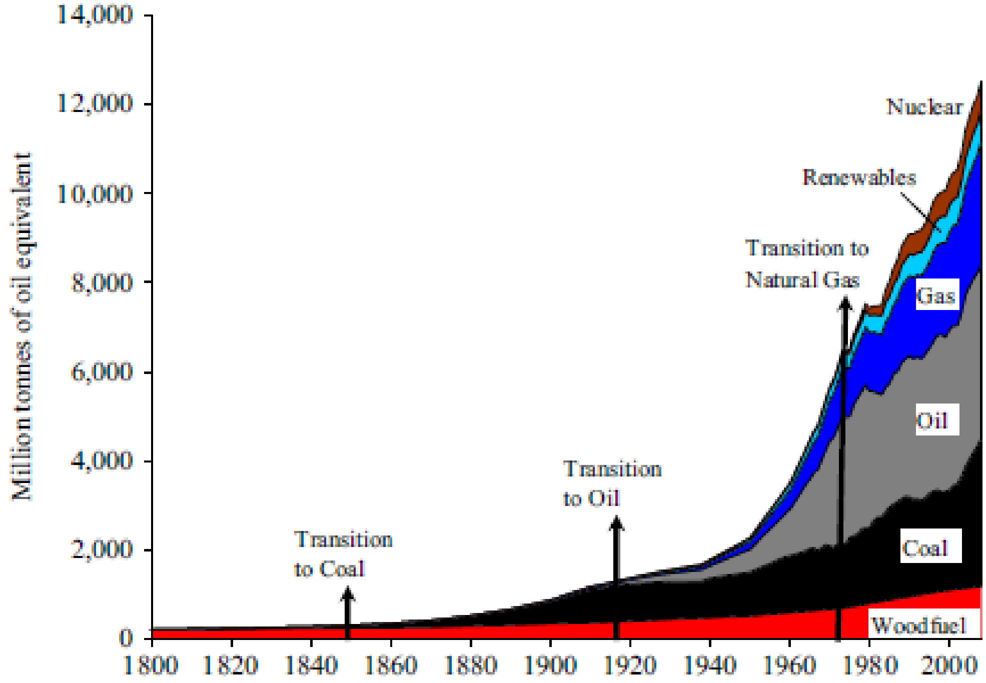
> *"Climate change is a defining challenge of our time … The energy sector is by far the largest source of greenhouse-gas emissions, accounting for more than two-thirds of the [global] total in 2010 … Energy has a crucial role to play in tackling climate change. Yet global energy consumption continues to increase, led by fossil fuels, which account for over 80% of global energy consumed, a share that has been increasing gradually since the mid-1990s."*
>
> *Redrawing the Energy-Climate Map*
>
> *The International Energy Agency (2013, p. 16)*

Energy is vital to advance living standards and create wealth. The ability of societies to meet the energy needs of growing populations and economies plays a central role in contributing towards human wellbeing. (Allen 2009; Fouquet 2011, p. 906; Rühl et al. 2012). The relative prosperity and power of nations can, in part, be related to the availability and use of energy (Lutzenhiser 1993; Shove et al. 1998). Since the industrial revolution, there have been a number of energy transitions; that is, changes in the sources of energy that an economic system is dependent on (Fouquet & Pearson 2012). For example, the total proportion of energy used globally has shifted from wood fuel to coal and then to oil and to gas (Fouquet 2009). Within these broader energy transitions, energy constraints have also caused short-term periods of disruption. A prominent example is the oil crisis in the 1970s that had a significant impact on the global economy and limited global economic growth for over a decade (Hamilton 2011).

Currently a significant energy transition is underway. This involves a movement away from a reliance on greenhouse intensive fossil fuels (e.g. coal, oil and gas) to cleaner, renewable sources of energy and towards more efficient use of energy. As Figure 2.1 highlights, this transition began relatively recently. In 2010, fossil fuels still accounted for 86% of global primary energy use (IEA 2011).

Figure 2.1: Global energy consumption and transitions 1800–2010

(Source: Fouquet 2009, p. 49)



The need to reduce reliance on fossil fuel-based energy supplies (due to the significant environmental, social and economic impacts of these energy sources) has driven the current transition. Impacts range from local pollution issues, such as the emission of poisonous sulfur dioxide gas that is associated with burning coal, to global climate change (Allen 2009; Fouquet 2011). Another important driver for change is the acknowledgement that fossil fuels are a finite resource. Supply is reliant on discovery of new sources and ultimately, fossil fuels may be prohibitively expensive to access or they may even become depleted (Campbell 2012). The use of fossil fuels may also be constrained by the need for global action to minimise global warming. To keep global warming below two degrees Celsius it has been estimated that only 20% of available fossil fuels should be burnt before 2050 (Leaton et al. 2013)

There are many factors that constrain the pace of the current energy transition. For example, not incorporating externalities such as social and environmental costs into the price of fossil fuels means that prices do not reflect the true cost of these fuels. This encourages ongoing use of fossil fuels rather than alternatives (IMF 2013;

National Research Council 2010). The relationship between economic growth, energy security and poverty eradication is another of the many significant challenges associated with the current energy transition. Where fossil fuels are the cheapest energy source in underdeveloped nations, then attempts to limit access to these sources may create a trade-off that affects fundamental social issues, such as poverty eradication (Bhattacharyya 2010).

Historically, energy transitions have occurred over long periods of between 40–120 years (Allen 2012; Fouquet & Pearson 2012). Unique to the current transition is that climate change scientists highlight the need for large-scale greenhouse gas mitigation to occur in the short-term through decarbonisation of the global energy system and other means such as carbon sequestration through forests (Pearson & Foxon 2012). Scientists have suggested that for the global climate to remain relatively stable, the concentration of greenhouse gas emissions needs to be maintained below 450 parts per million of carbon dioxide equivalent emissions. Scientists suggest that it is necessary to maintain average global temperature increases below two degrees Celsius in order to minimise the impacts of climate change (IPCC 2007). Economic research by Sir Nicholas Stern (2007) in the United Kingdom and Professor Ross Garnaut (2008) in Australia has demonstrated that the benefits of early action on climate change significantly outweigh the costs that are likely to be incurred in the longer term.[5]

Ultimately, the transition to a low carbon energy system requires the development and deployment of renewable energy generation technologies, such as wind and solar. However, due to the costs associated with these technologies and the advantages provided to fossil fuels through financial subsidies, decarbonising energy supplies rely heavily on government support. Supply-oriented government programs have had varied success in accelerating investment in and use of renewable energy sources (Carley 2009; Delmas & Montes-Sancho 2011; Verbruggen et al. 2010). Assuming that strong government support is made available globally, renewable energy sources are projected to progressively increase their share of global electricity

[5] Some economists have contested these studies. For example, discount rates used by Stern in his analysis have been challenged for being too low (Nordhaus 2007).

generation from 19% in 2008 to 33% by 2035. This trajectory for change from fossil fuels to renewable energy will not be sufficiently rapid in its own right to constrain the concentration of greenhouse gas emissions to the extent that they will limit the rise in global temperature below two degrees Celsius (IEA 2011). Due to the costs and lead time required to modify energy supply, demand side measures (i.e. measures that focus on the way energy is used rather than supplied) provide an important solution that can deliver cost-effective greenhouse gas reductions and deliver other significant environmental, social and economic benefits in the short-term. Energy efficiency is one of the most important of the demand management options available to organisations (Dunstan, Ross & Ghiotto 2011).

2.3 The benefits of energy efficiency improvement in organisations

> *"One of the greatest challenges of our time [is determining]how to fuel economic growth while also addressing climate change and the consequences of our dependence on fossil fuels. To meet this challenge head on, the nations of the world will need to rely on a plan full of energy options. … the simplest, most accessible and cheapest option is increasing energy efficiency and conservation. It is not only the cleanest option; it is also the easiest to implement and the quickest way to extend our energy supplies while also slashing carbon emissions."*
>
> *Andrew Liveris, Chief Executive Officer and Chairman, The Dow Chemical Company, USA (World Economic Forum 2010, p. 34)*

Defining energy efficiency

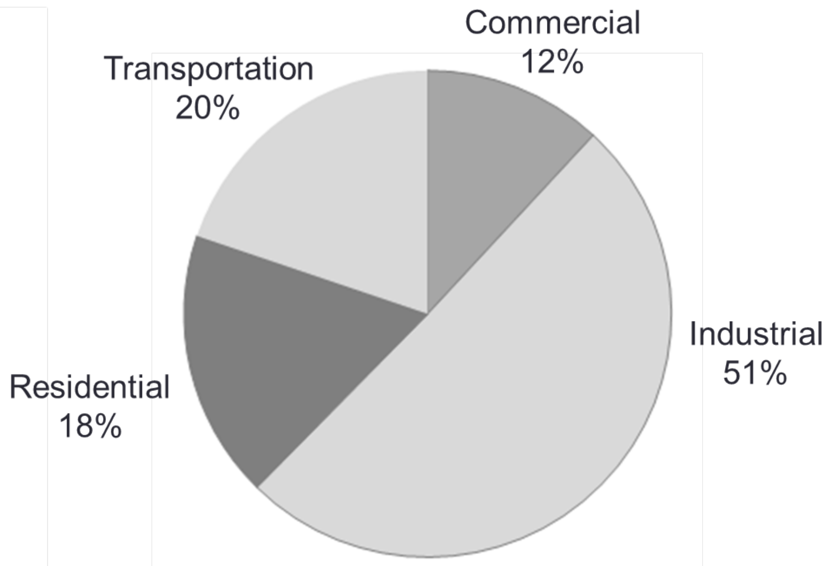
Energy efficiency, the focus of this thesis, refers to using less energy to produce the same amount of energy service or useful output (Jollands et al. 2010; Lovins 2004; Patterson 1996; World Energy Council 2008). Economists consider energy demand to be derived; that is, it is not the *energy* that consumers require, it is the benefits of these services delivered by end-use technology that utilise energy (Aune, Berker & Bye 2009; Croucher 2011b; Mills & Rosenfeld 1996). Energy services (or useful outputs) include heating, cooling, light, mechanical work and transportation (Ayres, Turton & Casten 2007; Nakicenovic 1995). Considered in this way, end user perspectives typically focus on the energy end-use technology and outputs, rather than the energy itself (Aune, Berker & Bye 2009). Therefore, unless outcomes or service requirements are compromised, end users are not disadvantaged when less energy is used to deliver the required outcomes or services.

Energy efficiency measures include changes in end-use technologies. For example, compact fluorescent light bulbs use around 80% less energy than a traditional incandescent and yet they can deliver the same useful light output and illumination (Radulovic, Skok & Kirincic 2010). Changes in behavioural practices are also an important way of improving energy efficiency. For example, encouraging people to turn off lights, equipment and air conditioning in buildings when they are not in use can yield significant energy savings at low or no cost (Masoso & Grobler 2010). Improving operational controls may also support improvements in energy efficiency. For example, an organisation may install light sensors or building automation systems that monitor and turn equipment off automatically (Rohdin & Thollander 2006). Indirectly, initiatives such as improving energy metering and data feedback mechanisms can provide information to support both automated and manual control of energy (Granderson, Piette & Ghatikar 2010).

The benefits and potential associated with improving energy efficiency in organisations

At a global level, significantly more energy is consumed by organisations than households. Figure 2.2 provides a breakdown of the proportion of primary energy use in the industrial, commercial, transportation and residential sectors. The electricity component of energy use has been calculated by accounting for the electricity consumed in each sector and then apportioning electricity losses. Electricity losses occur in the process of electricity generation, transmission, and distribution. Energy is consumed by organisations in the commercial sector (also referred to as the services sector) in many different types of buildings and to supply services such as traffic lights and water and sewer services. The commercial and residential sectors are typically highly electricity dependent which means that there is a greater proportion of energy losses compared to the industrial and transportation sectors which rely more on gas and other primary energy sources. Energy consumption in the industrial sector is diverse and includes activities associated with manufacturing and mining. Energy is consumed in the transportation sector to move goods and people in many different ways including by road, air and pipeline (U.S. Energy Information Administration 2013b). While tt is appropriate to examine the potential for improvement in each of these sectors, in this thesis the focus is on the use of energy by large energy consuming organisations in the industrial, commercial and transportation sectors.

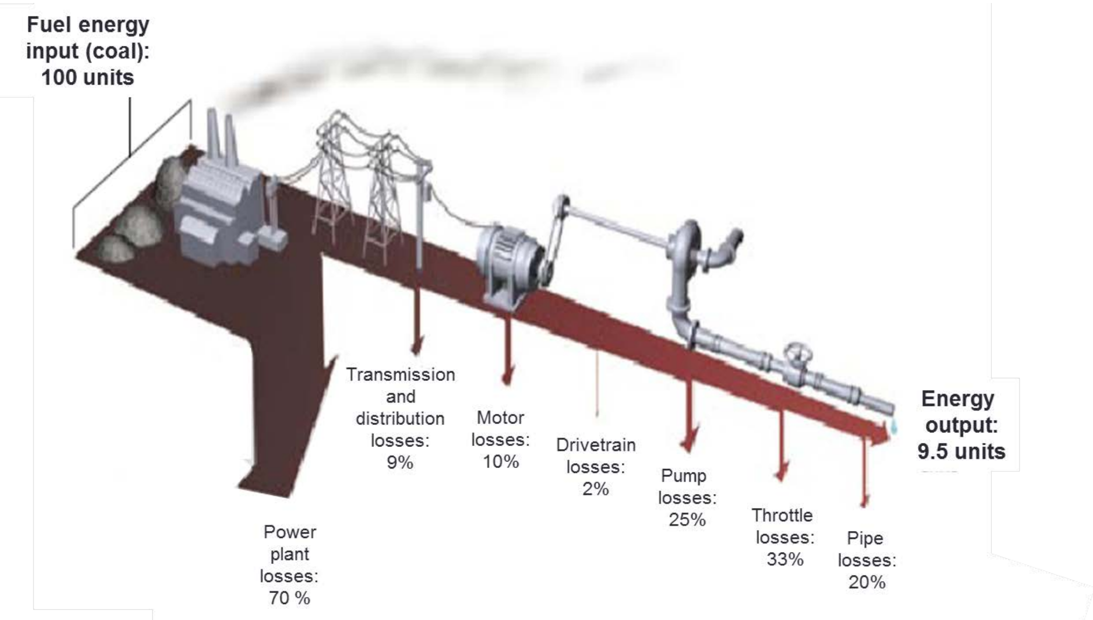
Figure 2.2: Global energy consumption by sector (primary energy)
(Source: Adapted from U.S. Energy Information Administration 2013a)



Numerous studies have attempted to quantify the size and financial potential of improving energy efficiency in organisations. For example, the consulting firm McKinsey & Company found that the implementation of cost-effective energy efficiency projects led to estimates that organisations in the United States could reduce energy demand by 23% to 2020 at an annual net saving of USD680 billion (Brennan 2013; Enkvist, Naucler & Rosander 2007). Participants in the Australian Energy Efficiency Opportunities program have implemented energy savings of 88.8 Petajoules (PJs) between the years 2006–2011. These energy savings represent around 1.5% of Australia's energy use. Businesses will obtain a collective benefit of an estimated AUD800m a year (van Moort et al. 2013). Energy efficiency improvements are also typically associated with improving productivity in firms by increasing output per unit of energy – both through reducing the energy intensity of the operation and improving the productivity of other input factors as well (Aguirre et al. 2011; Boyd & Pang 2000; Kounetas, Mourtos & Tsekouras 2012; Porter & van der Linde 1995). A number of other benefits include other operations and maintenance savings (Larsen et al. 2012), indoor air quality (Vine 2003) and worker productivity (Miller et al. 2009).

Organisations that implement energy efficiency measures are not the only beneficiaries. For example, changes in the end-use of energy deliver benefits throughout the energy supply chain. Figure 2.3 illustrates the energy losses that occur from a power plant burning coal to generate electricity through to the delivery of hot water in an industrial plant. The losses relate to electricity supply and use by the pump.

Figure 2.3: Energy losses across the electricity supply chain
(Source: Lovins 2005, p. 76)



At the economy level, energy efficiency can reduce demand for energy. This subsequently reduces the need for and costs associated with building new infrastructure (Brennan 2010). This benefit has been termed *negawatts* – a play on words highlighting the fact that energy efficiency is essentially the cheapest available *source* of energy (Lovins 1996; Steinberger, van Niel & Bourg 2009). Energy efficiency also contributes to national energy security by reducing demand for energy and the impact of supply disruptions (Jamasb & Pollitt 2008; Rogers-Hayden, Hatton & Lorenzoni 2011; Sovacool & Brown 2010).

The flow-on benefits of reducing the demand for energy infrastructure include a number of ‘hidden costs’ or externalities associated with power generation and transmission. A study by the National Research Council of the National Academies in the United States (National Research Council 2010) identified a range of costs not incorporated into electricity prices. These ‘externalities’ include:

- health effects associated with localised pollution around power stations
- potential impacts of climate change, and
- a range of environmental and social issues associated with the extraction of raw materials, processing and conversion to electricity or fuel, transmission and distribution.

Scott et al. (2008) analysed the macro-economic impact of the U.S. Department of Energy (U.S. DOE) programs targeting improvements in the energy efficiency of United States residential and commercial building stock. The analysis estimated that by the year 2030, these savings have the potential to:

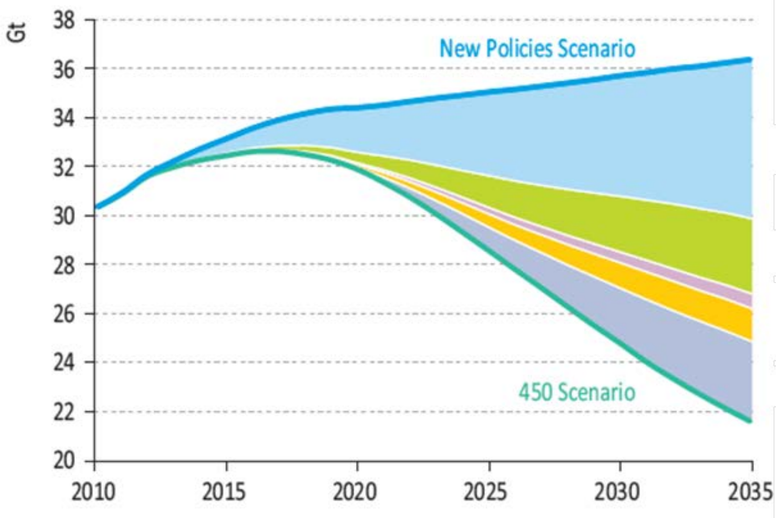
- increase employment by up to 446,000 jobs
- increase wage income by USD7.8b
- reduce the need for capital stock in the energy sector and closely related supporting industries by about USD207b (and the corresponding annual level of investment by USD13b), and
- create net capital savings that are available to grow the nation's future economy.

Modelling undertaken by the International Energy Agency (IEA) suggests that energy efficiency has a key role to play in the transition towards a low carbon energy system (see Figure 2.4). The top line on the graph is the expected trajectory of greenhouse gas emissions under a ‘New Policies Scenario’ (i.e. a situation in which countries implement all existing policies and declared policy intentions). This has been projected to lead to an increase in average temperature of more than 3.5 degrees Celsius. In order to meet the goal of maintaining greenhouse gas emissions (measured as carbon dioxide equivalence CO_2e) concentration in the atmosphere below 450 parts per million, the IEA estimates that energy efficiency has the potential to deliver over 72% of global reductions in energy-related CO_2 emissions in

2020 and 44% by 2035 (IEA 2011). The reason for this is that the technology is already available and much of it is cost-effective.

Figure 2.4: Projected abatement contributions under the 450 parts per million scenario

(Source: IEA 2011, p. 214)



	Abatement 2020	2035
Efficiency	72%	44%
Renewables	17%	21%
Biofuels	2%	4%
Nuclear	5%	9%
CCS	3%	22%
Total ($GtCO_2$)	2.5	14.8

This plethora of diverse benefits combined with the growing urgency to reduce greenhouse gas emissions due to climate change has made energy efficiency a prominent global policy and business issue (World Economic Forum 2010). In 2008, G8 energy ministers stated that: “promotion of energy efficiency in both the energy supply and demand chains in a cost-effective manner is a necessary prerequisite for addressing energy security and climate change while supporting economic growth” (Jollands et al. 2010, p. 6410).

2.4 The challenge of resolving the energy efficiency gap

> *"Despite the vital role that energy efficiency plays in cutting demand … only a small part of its economic potential is exploited… Four-fifths of the potential in the buildings sector and more than half in industry still remain untapped."*
>
> *World Energy Outlook 2012 (IEA 2012, p. 269)*

Despite the many benefits of energy efficiency to businesses (not least of which is the reduction in business operating costs), the evidence that there are many cost-effective energy efficiency projects not being implemented by business is a conundrum that has become known as 'the energy efficiency gap'. This term refers to the gap between the availability of cost-effective energy efficiency projects to firms and the extent to which such projects are implemented (Backlund et al. 2012; Jaffe & Stavins 1994a; Patterson 1996; Sanstad & Howarth 1994). This notion has been presented in a number of different ways (Table 2.1). Underpinning each definition of the energy efficiency gap is an acknowledgement that energy efficiency projects that *appear* to be beneficial to firms and *should* (under usual conditions) be implemented, are not actually being implemented.

Table 2.1: Defining the energy efficiency gap

Author	Definition of the energy efficiency gap
DeCanio (1998, p. 441)	"… the situation where there is abundant evidence that highly profitable energy-saving opportunities exist, yet the technologies embodying these opportunities have not spread universally throughout the economy ..."
Brown (2001, p. 1198)	"… the difference between the actual level of investment in energy efficiency and the higher level that would be cost beneficial from the consumer's (i.e., the individual's or firm's) point of view ..."
Kounetas & Tsekouras (2008, p. 2518)	"… the case in which firms, presumed to behave rationally and to be economically efficient, do not undertake capital investment projects on energy efficiency technologies, although they are preferable in terms of profitability and risk to other non-related to energy efficiency technologies projects …"

In part, the phenomenon of the energy efficiency gap is due to the complexity of energy use in business and society. Consumers use energy to provide a range of different services, such as heating, power, transport and lighting (Fouquet 2010). Services depend on user behaviour in both selecting and using appliances. Some decisions are not available to the consumer as they may be 'designed in' (or not) by equipment suppliers. For example, the decisions made by a water utility can impact on both the cost and environmental impact of the water supply to businesses and households (Crittenden, Benn & Dunphy 2011; Pamminger & Narangala 2009). Within organisations themselves business structures and personal influence by managers may influence the priority placed on energy efficiency improvement (Cebon 1992; Paton 2001). Therefore, many different stakeholders influence the way in which energy is used by a consumer – some of which the consumer can control and others that it cannot control. Unlike energy supply issues which are relatively centralised, decisions about energy efficiency are decentralised, involving multiple decisions at different points in time by a large number of stakeholders (Samouilidis, Berahas & Psarras 1983).

Using the example of a commercial building, energy-related decisions are embedded into the building itself (Ramesh, Prakash & Shukla 2010; Tsai et al. 2011), can be influenced by the purchase and use of equipment by tenants throughout its life (Webber et al. 2006) and may be controlled by the building manager (Aune, Berker & Bye 2009; Costa et al. 2012; Dilling & Farhar 2007; Lewis, Elmualim & Riley 2011; Lindkvist & Elmualim 2010; Yik, Lee & Ng 2002) with the capacity for control being influenced by the information systems incorporated into the building (Lawrence et al. 2012). Of note is that, even as 'greener and more efficient buildings' are designed and being built, such buildings typically require high levels of maintenance and management and there may be a significant disparity between the level of design and the extent to which a building actually performs (Bordass & Leaman 2005; Bordass & Leaman 1997; Leaman & Bordass 2007). The complexity of energy use decisions and actions highlight the point that resolving the energy efficiency gap is complex. The Chapter 3 examines the important role that improved energy management practices in organisations and government policies can play in addressing the energy efficiency gap.

2.5 Conclusion

This chapter has established the environmental, social and economic context within which the research has been undertaken. It highlights the significant role that organisations can play in reducing greenhouse gas emissions and delivering broad societal benefits through the improvement of their energy efficiency performance. However, despite the potential benefits, there is a gap between the availability of cost-effective energy efficiency projects and the extent to which they are implemented by organisations. Building on this important background context, Chapter 3 examines the role that effective energy management practices can play in resolving the energy efficiency gap and the government policies that have been designed to influence energy management practices.