UNIVERSITY OF SOUTHERN QUEENSLAND

UTILIZING A MARGINAL ABATEMENT COST CURVE APPROACH TO DEVELOP A LOW GREENHOUSE GAS PLAN: CASE STUDY OF ENERGY MANAGEMENT IN A RURAL REGION (TOOWOOMBA-AUSTRALIA) ACCOUNTING FOR HUMAN BEHAVIOUR

A Dissertation submitted

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ABSTRACT

The global warming phenomenon has become an international issue which requires effort to avoid and control the concentration of greenhouse gases (GHGs). At the same time, despite various attempts, developed countries need to put more effort and attention into dealing with this issue. Many studies have been conducted on reducing GHGs globally and nationally. The majority of these studies have focused at a national or sectorial level, particularly in the industrial sector.

This study focuses on stationary energy. There are two main ways to reduce GHGs, particularly CO_2. One is to replace carbon-based fuels with renewables. The other is to reduce consumption. To achieve further GHG emission reductions, improvements to behavioural change regarding the use of energy are an emerging area of research that has significant implications for policy.

One method adopted for reducing GHG is the MACC approach. In recent years, the need for more reductions in emissions with low costs has increased suitable strategies adopted at both an organisation and region level. However, many previous studies have been undertaken with a focus on estimated data. Accordingly, this study seeks to establish to what extent using actual data will help decision makers.

The findings of this research indicate that organisations are seeking a more accurate approach to save energy, reduce emissions, and determine the impact of users' behaviour when using abatement activities. Organisations are planning to use management accounting methods such as MACC when measuring the cost of abatement or reduction in environmental costs for more effective decision-making. This study developed a concept by using actual data in MACC. The design established support for organisations to meet data accuracy needs.

This research provides important insights, particularly in promoting energy saving and emission reduction at the organisation level. The results confirmed the main assumptions and purpose underpinning this research.

CERTIFICATION OF DISSERTATION

I certify that the ideas, analyses and conclusions reported in this thesis are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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LIST OF ABBREVIATIONS

ABC	Activity Based Costing
BAU	Business as usual
CAC	Command and control
CO_2	Carbon dioxide
CP	Carbon price
CPRS	Carbon Pollution Reduction Scheme
CH_4	Methane
EMA	Environmental Management Accounting
ETPCN	Ecological Transformation Pathways to Carbon Neutrality
ETSs	Emissions trading schemes
GDP	Gross Domestic Product
FC	Fluorocarbon
FCA	Full Cost Assessment
FCEA	Full Cost Environmental Accounting
GHGs	Greenhouse Gases
HFCs	Hydro fluorocarbons
IPCC	Intergovernmental Panel on Climate Change
IPMVP	International Performance Measurement and Verification Protocol
IRR	Internal Rate of Return
LCA	Life Cycle Analysis
LCECA	Life Cycle External Costs Assessment
MACC	Marginal Abatement Cost Curve
MC	Marginal cost
NPV	Net present value
N_2O	Nitrous oxide
NGERA	National Greenhouse and Energy Report Act
NGER	National Energy Reporting Regulations
PCA	Partnership for Climate Action
PP	Payback period
RGGI	Regional Greenhouse Gas Initiative
SF_6	Sulphur hexafluoride
SPC	Shadow Price of Carbon
TCA	Total Cost Accounting

CANDIDATE’S PUBLICATIONS

Almihoub, AAA, Mula, JM & Rahman, MM 2013a, 'Marginal Abatement Cost Curves (MACCs): Important Approaches to Obtain (Firm and Sector) Greenhouse Gases (GHGs) Reduction', *International Journal of Economics and Finance*, vol. 5, no. 5, p. p35.

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CHAPTER 1: INTRODUCTION

1.1 Background

The broad acceptance of the existence of human-induced climate change, jointly with the principal role of greenhouse gases (GHGs), has led to a rising importance in characterising regional contributions of anthropogenic (caused or produced by humans) GHGs emissions (Pall et al. 2011). In the last few years, emissions trading has emerged as the chief tool for controlling anthropogenic emissions of GHGs (Wetzelaer et al. 2007). The aim is to reduce GHGs while providing economic value, which critically depends on many factors such as emission reduction costs, policies governing international trading schemes, and other flexible mechanisms (Halsnæs & Shukla 2008). In addition, GHGs emissions are externalities and signify the most formidable market failure the world has seen (Calthrop et al. 2012). Most countries produce emissions and people worldwide are already suffering from past emissions; and current emissions will have significant potentially catastrophic impacts in the future. Therefore, these emissions are not ordinary, localised externalities (Stern 2008). There have been many attempts to reduce global emissions using a range of scales with growing attention to the significance of recently emerging local action (Bulkeley & Betsill 2003; Burton 2007; Davies 2005; Lindseth 2004). The essential premise of the local argument in climate change mitigation is that as the greater part of GHG emissions occur at the local level, local action plays a vital role in emissions reduction efforts (Burton 2007).

Many questions have been raised as to how to effectively reduce carbon emissions (Kesicki 2010b). Marginal abatement cost curves (MACCs) are frequently used heuristically to reveal what can be achieved from emissions reduction (Ellerman & Decaux 1998). A MACC is illustrated as a line graph that indicates the cost, typically in dollars per tonne of CO_2 equivalents, associated with the last unit (marginal cost) of emission abatement for different amounts of emission reduction, generally in million tons of CO_2 (Kesicki 2010b). The difficulty in implementing carbon abatement policies is caused by scientific uncertainty about the impact of carbon emissions on the atmosphere (Howarth 2001). As well, the underlying assumptions, measures and methodologies used to create MACCs to identify abatement interventions have had little scrutiny and validation (Vasa 2012). Thus, there is limited agreement on an appropriate MACC methodology (Kesicki & Strachan 2011; Shishlov & Bellassen 2012).

Users have limited understanding of evaluating and applying the sorts of policies that could be considered necessary for the abatement of GHGs emissions (Ellerman & Decaux 1998; Gale 2006). In a research study, it has been stated that expectations of future policy and reinforcement of future competitiveness are basic reasons driving full-cost accounting processes (Atkinson 2000). Full environmental cost accounting and life-cycle costing offers information that managers require to more effectively manage companies' environmental strategies to reduce long-term environmental effects and corporate costs (Epstein 1996).

Therefore, this study assesses the adequacy of a MACC methodology to help lower GHG emissions using a case study of energy management of an organisation in the regional area of Toowoomba. Moreover, this research attempts to assess levels of emissions of GHGs and analyse costs of energy use. It focuses on the energy and emissions reduction of organisations through the application of MACCs. The study evaluates the extent to which the interventions succeeded in changing behaviour and reducing energy use. Human behaviour could be an important element in reducing emissions and needs more emphasis, particularly for governments and businesses, in recognising and assessing behavioural change interventions. These could be appropriate tools to assist companies reduce their emissions. The sources of data for this research are historical data, surveys and face-to-face interviews with senior executives in accounting and environment management.

1.2 Statement of the problem

Global warming has become an international concern. Many countries worldwide, especially developed countries, have made it a priority. The global warming phenomenon requires more effort to avoid and control concentrations of GHGs (Bosetti et al. 2009; Grubb, MJ et al. 2002). Worldwide, climate warming has been attributed to industrialisation and intensive agriculture, particularly over the last 50 years (Sathiendrakumar 2003a).

The scientific consensus is that climate warming is likely because of increasing GHG emissions from industrial activities (Budescu et al. 2009). Human activities also have negative significant impacts on the environment; but industrial activities are at the forefront. Although governments in last decades have imposed many regulations to improve firms' environmental performances they were not efficient enough to significantly cut emissions (Stiglitz 2002). Currently some firms have realised the possible advantages that they can obtain from consciously adopting more pro-active behaviour towards the environment (Allcott & Mullainathan 2010; Tyteca 1996), but it is not easy to identify suitable techniques for implementation.

There are many motives for firms when considering the environment, such as societal pressures and concerns for corporate social responsibility, as well as adhering to government requirements and pressures from employees, neighbours, the general public, environmental groups and regulatory agencies (Acutt et al. 2004). Companies are now eager to monitor their emission levels and to understand how to reduce these emissions (Bréchet, T. & Jouvet, P. A. 2009). Therefore, there is an increasing demand for tools that could allow firms to properly and objectively quantify related environmental impacts (Tyteca 1996), however, it is not easy for firms to identify suitable techniques to evaluate alternative investments options for abatement.

Firms attempting to quantify environmental impacts are encountering many difficulties due to classification of data, collation and methodological approach used. Data on environment impacts are kept confidential because some firms are not required to disclose emissions at this stage and feel they may be declaring liabilities (Mosma & Olson 2007). Also, information on emissions is available only in a highly aggregated form (Strachan et al. 2008). Corporations and managers must learn to frame environmental improvements in terms of resources productivity, or the efficiency and effectiveness through which corporations and their customers use resources (Bauman 2004).

Energy efficiency efforts by organisations can assist in cutting corporation costs, decreasing dependency on energy imports and mitigating GHG emissions (Böhm & GmbH 2006). At the same time, firms are facing many difficulties in measuring abatement and control of environmental costs and contaminants (Bose 2006; Gale 2006; Kesicki 2010a; Petcharat & Mula 2010b; Pramanik. et al. 2007; Qian & Burritt 2007).

In order for energy user behavioural change to become more energy efficient, people and decision-makers must have accurate, accessible and understandable information about energy issues. Consequently, they would develop a more positive attitude towards energy use for energy saving; and modify their behaviour to improve energy efficiency (Carlsson-Kanyama & Lindén 2007; Valkila 2013). However, the impact is not simple: there are a considerable number of studies which demonstrate much more complicated and conflicting links between people's knowledge, attitudes and behavioural changes (Hu et al. 2003; Legris et al. 2003; Valkila 2013).

In some situations, firms could invest in more than simple abatement but they need more strategies for them to empirically support additional abatement measures. It is necessary for firms to understand how more efficient abatement can be pursued inside each firm. A marginal abatement cost curve approach could offer a way to reduce emissions by lowering costs through capital expenditure (Molyneaux et al. 2010). Energy efficiency policies are one of the strategies that could be used to underpin economic development and reduce GHG emissions at the same time (Halsnæs & Shukla 2008).

A study has found that the rise of CO_2 concentrations in the environment (between 1870 and 2000) was about 30% (Sathiendrakumar 2003b). The possibility of measuring emission reductions of GHGs is important and these reductions should be visible as abatement activities. Therefore, measuring GHGs emissions needs an agreed norm (Halsnæs & Shukla 2008; O'Brien 2012). Each country has a specific MACC independent of the behaviour of the rest of the globe (Den Elzen & De Moor 2002). Most approaches adopt theoretical estimates of usage and emissions, as well as savings and achievable CO_2 reductions. Accordingly, the main concerns about a MACC approach to reducing carbon emissions are accuracy of models used and underlying assumptions made, which are reflected in a lack of confidence in solutions obtained. Therefore, the problem is to what extent does using actual data help decision makers. Thus, this study seeks to answer the following main research questions:

(**RQ1)**: **Can MACCs provide an accurate and simple interpretation of relative and total costs for abatement?**

(RQ2): **Does user behaviour resulting from abatement activities impact on MACC methodologies?**

1.3 Motivation and scope

The study is motivated by the appearance of GHG reduction regulations in advanced nations, including Australia, and the debate on their implications for sustainable economic activities. The Federal Government and all Australian state governments seem to be interested in pursuing emission reductions (Christoff 2005). Australia has the highest per capita GHG emissions in the world, which could severely impact its climate (Garnaut 2008; Shiel 2009). It has experienced a major rise in energy consumption as part of its fast economic growth (Baniyounes 2012).

Companies display a great variety of environmental performance in spite of widely-acknowledged weaknesses in regulatory frameworks, particularly in developed economies (Pandey et al. 2006). These facts create issues for conventional thinking about controlling a firm's pollution outputs. Emissions of GHGs, which are still not priced in many countries, drive the emerging observed and forecasted effects of climate change on the planet. This damage has real value and can be monetised, allowing for a hypothetical social cost of carbon to be estimated (Hardisty 2009).

While detailed abatement studies are not often found in the literature, examinations of abatement technologies and associated costs are increasing—although most studies are confidential or unavailable (Beaumont et al. 2003). The majority of available research has been based on national GHG emissions (Maya & Fenhann 1994; Smith et al. 2009; Verbruggen et al. 2001; Wickborn 1996) and are particular to individual industrial sectors (Beaumont, N. & Tinch, R. 2004; Nadeau 1997). This study, unlike sectoral and national studies previously published, works to assess a firm's ability to apply an appropriate MACC approach.

Conducting firm studies could improve the ability to comprehend the costs of reducing carbon emissions and thus assess alternative policy options (Vandenbergh et al. 2007; Weyant, J. 1993).

Many companies need an effective tool to reduce their emissions. To perform these cuts, they need to know how to begin and what the priorities are. There are, in the main, two uses of energy. Stationary energy is used in the form of electricity in building, industry and other sectors. Motion energy is used for transportation-oil and gas. This study focuses on stationary energy. There are two main ways to reduce GHGs, particularly CO_2. One is to replace carbon-based fuels with renewables; the other is to reduce consumption. This study investigates the latter only.

1.4 Research objectives

This study seeks to achieve five main objectives, namely:

1- To identify the differences between estimated (theoretical) and actual MACC models at an organisation level.
2- To develop MACC methodology.
3- To examine the impact of energy management knowledge on users' behaviour to change their energy usage.
4- To examine the impact of users' attitudes on energy saving initiatives.
5- To examine the impact of user-acceptance of energy abatement initiatives on MACC methodology applied.

1.5 Expected contributions

To the literature

Scant published research is available on the most applicable methodology to adopt for calculating a MACC at a firm level. Most studies have remained as theoretical studies with little measurement of actual interventions to test theory, assumptions and methodologies. There is a lack of studies that have focused on MACCs relating to firms in regional areas, thus controlling for some exogenous effects. Therefore, the proposed research will contribute to the literature in several ways. First, the study will develop an appropriately tested MACC at an organisation level by using actual data. Second, the proposed research extends prior research that links country and sector MACCs with MACCs of firms. Third, evidence will be provided to justify the use of certain MACC methodologies to organisation level. Finally, the study will examine actual changes to environmental policies of the organisation that affect human behaviour regarding energy use. These changes will explain the differences as a result of interventions. The application of mitigating initiatives expected and actual changes in the policies of the organisation will be through the assessment of behavioural change. This study investigates behavioural change related to users of energy and impacts to energy management, as well as emissions at an organisation level.

To practice

One of the main purposes of this study is to provide an approach for all firms to implement reductions in GHGs related to stationary energy use. Therefore, it is expected to contribute to practice in several ways. Firstly, a practical methodology will be tested that can be adopted to reduce concerns about the effects of GHGs abatement strategies by business, thus providing evidence that the MACC approach is valid. Secondly, a firm's management will be exposed to the potential advantages of applying MACCs to help reduce energy usage and emissions. Additionally, the proposed research is expected to help regulators in regions understand the role of MACCs which, in turn, will help them in setting future regulations and strategies. Figure 1.1 sets out the structural framework for this dissertation.

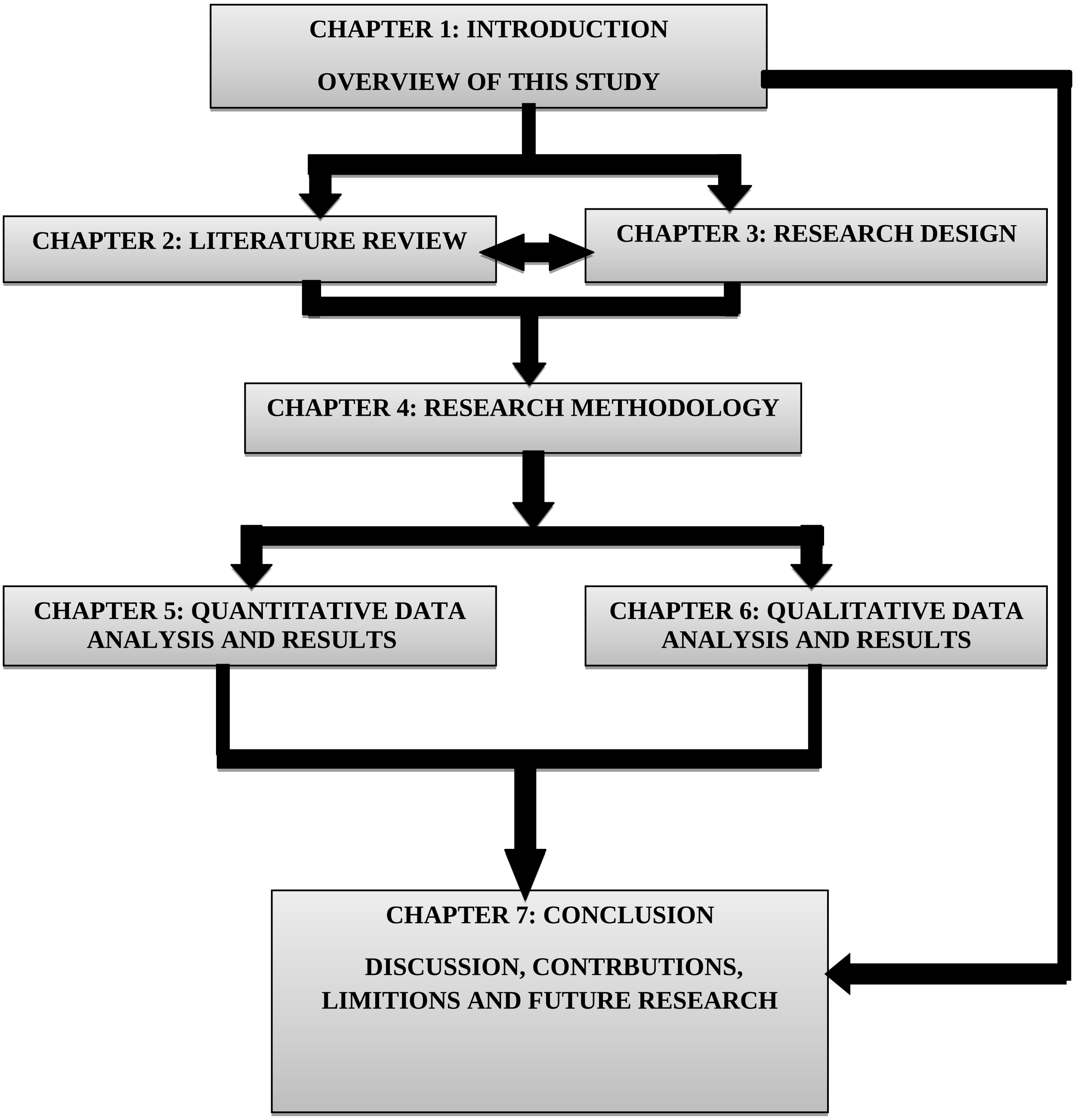

Figure 1.1 Structural framework of the thesis

Source: Developed for this study

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter 1 provides an overview of this study by presenting the background, statement of the problem, motivations, the research objectives and the contributions. Chapter 2 reviews the current literature on energy use; and its relationship to abatement of GHG emissions by firms is critically reviewed. Special considerations are given to energy, GHGs, accounting tools and methods, MACCs, sectoral analysis, energy emissions management and behaviour aspects. The literature reviewed identifies and discusses key research issues and their relevance to this study. The review helps justify the reasons for conducting this research and in identifying the research gaps; identified research issues range from general to specific. One of these has been a growing concern about energy use and its adverse impact on the environment.

2.2 Energy

Energy is the prime mover for the wealth of communities and their quality of life. For more than a century, in many countries, cheap energy using abundant fossil fuels supported industrialisation (Van Vuuren et al. 2003). While this increased the living standards of these countries, it subsequently led to more consumption of energy (Soytas et al. 2007). This has presented a number of key issues and challenges such as rising energy consumption and emissions (Bauen 2006; Perez-Lombard et al. 2008; Sadorsky 2009).

Energy consumption has increased worldwide by 30% over the last 25 years. Industrialised states consume four times more than the world average (Lopes et al. 2005). As economic growth is being achieved in countries such as China, India and Brazil (Bauen 2006), energy consumption is expected to increase (Keleş 2011; Lenzen et al. 2006; Sathaye et al. 1996). A number of studies indicate that income growth per capita and lifestyle are the most powerful drivers of energy consumption and emissions (Hamilton & Turton 2002; Soytas et al. 2007).

Energy efficiency can play a major role in reducing environmental impacts. A number of studies (Bernard & Côté 2005; Neelis et al. 2007; Ramírez & Worrell 2006) refer to the cumulative energy demands of products directly and indirectly during most stages of production. These include energy consumed during manufacturing, extraction, disposal of raw materials and other additions (Huijbregts et al. 2006). These studies gained importance socially and politically because of their predicted increases in energy consumption.

Energy consumption in production processes is evaluated and is an integral part of energy production (Bernard & Côté 2005; Neelis et al. 2007; Ramírez & Worrell 2006). These studies show the way that the flow of energy affects consumption. They also provide evidence based on energy efficiency; however, they fail to describe environmental impacts derived from consumption of different energy sources, which include vital data such as depletion of resources, land use, depletion of the ozone layer, global warming, toxicity and acidification (Bernard & Côté 2005; Neelis et al.

2007; Ramírez & Worrell 2006). In this regard, Huijbregts et al. (2006) found that cumulative fossil energy estimates may not include other important processes during production such as energy production, production of materials or transportation. The existence of these other important effects is common scientific knowledge, not only for fossil fuels but also for other energy sources (Herva et al. 2011).

The consumption of energy can result from consuming anything. Bullard et al. (1978, p. 267) state, "When we consume anything, we consume energy". This highlights the scale of the challenge that faces an organisation in reducing environmental impacts resulting from energy consumption in contemporary world economies (Stiglitz & Walsh 2005). Historically, energy price signals have been distorted by support from various types of government policies in an attempt to push economic activity and growth at the expense of the environment (McKibbin et al. 2010). Some experts on the environment and the economy (Figge & Hahn 2004; Hawken 1994; McKibbin et al. 2010) consider that traditional market economic theory is not appropriate and that it is inconsistent with the environment and intergenerational sustainability (Sinton et al. 2005). Therefore, economists may need to improve traditional market theory to deal appropriately with emissions from consumption of energy.

Studies have been conducted on energy audits and the results of energy analyses for various sectors of energy users (Fromme 1996; Ibrik & Mahmoud 2005; Ross 1987; ThollanderKarlssonSoderstrom, et al. 2005). The foremost energy-saving measures contain the use of more efficient electric motors, lighting facilities, refrigerators, air compressors, boilers, and furnaces (ThollanderKarlssonSöderström, et al. 2005). Energy efficiency is a main concern since there can be a reduction of 10-30 per cent in greenhouse gas emissions for little to no cost through improved energy efficiency (Ghaddar & Mezher 1999). Energy efficiency improvements and lighting could provide 14% reductions in CO_2 without any cost (Nguyen & Ha-Duong 2009). Moreover, the development of efficiency techniques are improving and the implementation of financing mechanisms that encourage the adoption of achieving further reductions should be encouraged (Chan et al. 2007).

The literature on energy economics contains a wide range of studies dealing with the establishment of the relationship between energy consumption and economic growth, energy demand in homes and demand for energy by industries (Perez-Lombard et al. 2008). Much of the research has been conducted to illustrate the relationship between energy consumption and climate change (Chan et al. 2007; Priambodo & Kumar 2001; Sahu & Narayanan 2010).

Operations such as pumping, ventilation, internal transport, compressed air, lighting, heating, and tap water are often not identified in firms' emission reductions (Patrik Thollander 2004). Firms do not consider energy savings in production. The reasons for this include a long history of low electricity prices (Gebremedhin & Systems 2003), and the lack of awareness of solutions and problems, limited capital, repayment periods over a long time, limited experience of staff and resistance to a change of personnel (Möllersten 2002). However, energy is a significant cost which can be controlled, and there are opportunities to achieve significant savings in support of operations (Bosetti et al. 2009; Patrik Thollander 2004).

The energy sector is responsible for most GHG emissions in Australia (Riedy 2007). In 2007, the percentage of energy production and consumption of energy accounted for 68.4%, which translates to net emissions in Australia of 408.2 million tonnes of CO_2-e (Pink 2010). Of this, 370.5 million tonnes of emissions were from burning fossil fuels (mainly for electricity generation and manufacturing), and 37.7 million tonnes were from fugitive emissions (mainly related to coal mining) between 1990 and 2007. Therefore, emissions from energy rose by 42.5 %. In 2007–08, Australia's total local energy use was 5,772 petajoules (PJ); from 1975 to 2008, Australia's total energy use increased by 111%—up from 2,731 PJ in 1975–76. Figure 2.1 represents the compound annual growth of energy use of approximately 2.4% (Pink 2010).

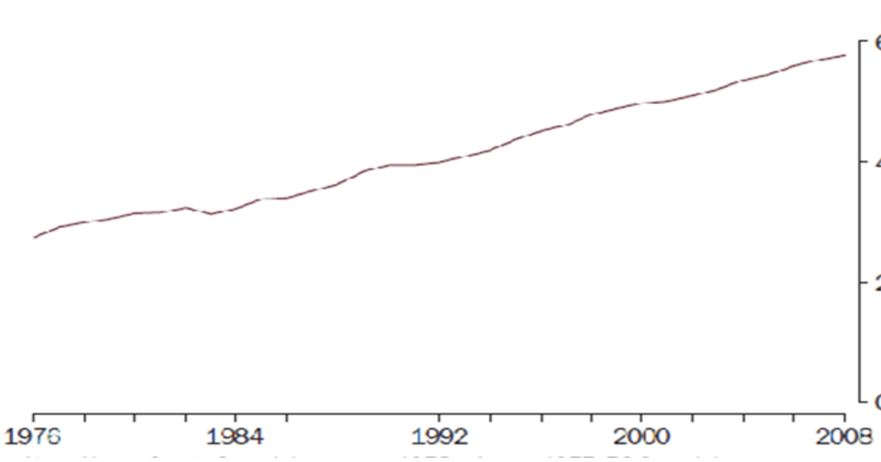

Figure 2.1 Total energy use in Australia 1976-2008
Source: (Pink 2010)

Since emissions have been identified as arising primarily from the consumption of energy, climate change is increasingly a global concern (Budescu et al. 2009). Improving the efficiency of energy use is the key to abating GHG emissions (Chan et al. 2007). Therefore, researchers of energy, organisations and governments need to develop methods to assess the efficiency of energy use. Such methods of assessment can be used for the development of energy policy and may help to reduce emissions of GHGs at the same time (Saidur et al. 2009).

To achieve the goal of stability or reduction in emissions, a major change to current activities needs to happen in a range of sectors, including energy, transport, agriculture, manufacturing and building (Blok et al. 2001; Noller 2005). Thus, mitigating GHG emissions from these sectors offers the best means of reducing overall GHG emissions.

2.3 GHGs

It is thought by several scientists that rising levels of GHG emissions, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydro fluorocarbon (HFCs), and per fluorocarbon (FC) (Akter & Bennett 2011) may negatively impact the climate, increase sea levels, and threaten the natural environment, survival of the human race and its surrounding ecosystems (Sathiendrakumar 2003b). The Intergovernmental Panel on Climate Change (IPCC) has developed four scenarios that consider different sets of assumptions. Under these scenarios, global GHG emissions are expected to grow 39-89% by 2025 and 63-

235% by 2050, depending on underlying assumptions. Gross Domestic Product (GDP) and population are the strongest determinants of emissions trends in most scenarios. The wide range in projections reflects these differing assumptions (Baumert et al. 2005).

Among numerous human activities that produce GHGs, energy use is by far the largest source of emissions (Quadrelli & Peterson 2007). Anthropogenic pollution represents more than 80% of GHG emissions from production, handling, transformation, and consumption of all types of goods (Akpan & Akpan 2011; Quadrelli & Peterson 2007). The energy sector is the largest contributor to the production of GHGs' emitting process of which CO_2 is the largest component (International Energy Agency 2007). Secondary combustion and oxidation of carbon from fuels is responsible for about 95% of energy-related emissions. As a result, CO_2 from energy represents about 80% of global emissions of anthropogenic GHG (Quadrelli & Peterson 2007). This percentage varies greatly from country to country according to different national approaches to energy use.

Carbon pollution is purported to be the main cause of climate change—which has a negative impact on the environment and also influences food production, as well as everyone's way of life. Australia has joined over 89 industrial countries representing 80% of global emissions and 90% of the world's economy (NGERA 2009). Australia emits approximately 500 million tonnes of carbon pollution every year, making it one of the top 20 polluting countries in the world (Australia Government 2012). The Government's long-term target for carbon pollution reduction has been raised from the year 2000 level of 60% to 80% by 2050'(Baniyounes et al. 2012). The Government will help businesses improve their energy efficiency through a range of measures, including $1.2 billion for the Clean Technology Program (Australia Government 2012).

While developing countries contributed 42% of carbon dioxide in world emissions from energy in 2002, these countries are expected to contribute 53% by 2025 (Figure 2.2.). Developing countries are usually referred to as countries not included in Annex I[*] of the Kyoto Protocol (Auckland et al. 2002; BCASF 2007; Macintosh 2010; Noble & Scholes 2001). They were not asked to reduce emissions in recognition of the fact that developed countries have contributed mostly to rising GHGs (BCASF 2007).

Currently, all countries worldwide are dealing with issues of energy security and global warming, and are attempting to address all of these problems. Along with growth in energy use comes the rise in emissions of CO_2 (Perez-Lombard et al. 2008;

* These are the 39 emissions-capped industrialised countries and economies in transition listed in Annex B of the Kyoto Protocol. Legally binding emission reduction obligations for Annex B countries range from an 8% decrease (EC) to a 10% increase (Iceland) on 1990 levels by the first commitment period of the Protocol, 2008-2012 (Auckland et al. 2002; Macintosh 2010). Annex I and Annex B are used interchangeably in some papers. However, Annex I refers to the 36 industrialised countries and economies in transition listed in Annex I of the United Nations Framework Convention on Climate Change. They have a non-binding commitment to reduce their GHG emissions to 1990 levels by 2000 (Auckland et al. 2002; Macintosh 2010).

Sadorsky 2009). In 2005, the world's top five emitters, in order of emission, were the United States, China, Russia, Japan, and India. These countries emitted CO_2 emissions of 55% of energy-related global CO_2 (International Energy Agency 2007). By 2030, the top five emitters (in terms of emissions), in order, are estimated to be China, United States, India, Russia and Japan and their share is forecasted to increase to 59%. Increasing concentrations of GHGs in the atmosphere are contributing to climate change and rising temperatures. According to the IPCC (2007a) CO_2 concentration in the atmosphere needs to be stabilised at 450 ppm (IPCC 2007). Currently, it is about 350-400 ppm (International Energy Agency 2007, p. 206). The increase of CO_2 is a global problem requiring a global solution (International Energy Agency 2007, p. 50). Therefore, it is necessary that all countries quickly find ways to reduce their emissions.

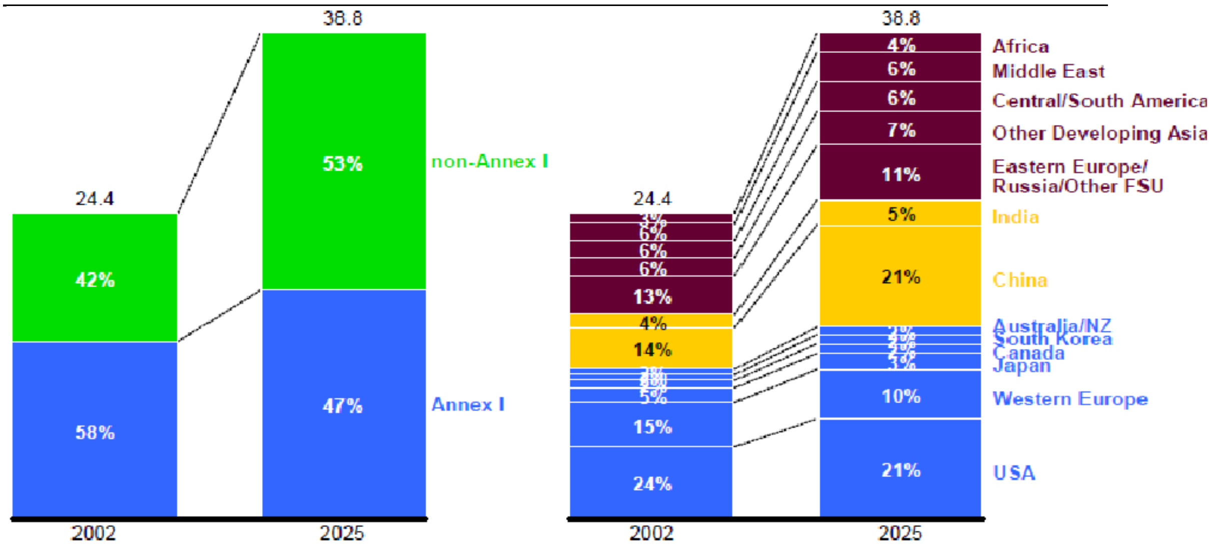

Figure 2.2 Global emissions—2002 and 2025

Source: (BCASF 2007)

The need for a coordinated universal effort to manage climate change has arisen because the atmosphere is a public resource. The important aspects here include how much global abatement should be undertaken, how it should be shared among developed and developing countries, and what abatement instruments should be used (Guest 2009).

GHGs seem to be uniformly mixed pollutants. For instance, does emitting one tonne of GHGs from somewhere on the planet have a similar influence of one tonne emitted anywhere else in the world (Stern et al. 2006)? When this is interpreted into the dialect of abatement strategies, it means that the location of where a reduction in GHG emissions occurs is not important. What matters is whether decreases in emissions are efficiently possible on an international basis given the information that costs of abating GHGs emissions vary considerably between countries. Thus, there are now many local and regional governments following an approved form of recording their GHG emissions, establishing climate change action policies, and setting emission reduction targets (Lutsey & Sperling 2008).

The trading system in the European Union is the largest emissions trading scheme in the transnational world, covering more than 10,000 installations in the energy and industrial sectors in its Member States (Green et al. 2009). Together, these facilities account for nearly half of the carbon dioxide emissions for the European Union (Ellerman & Buchner 2007). The European Commission intends to adopt a regulation for the verification and certification of the European Union to allow further adoption and more widespread installations of trading systems by 2012 (De Brauw & Westbroek 2009). Emissions trading schemes (ETSs) are an important segment of European industry, which is incorporating the price of CO_2 emissions into their daily production decisions (Martinov-Bennie & Hoffman 2012; Nelson et al. 2010).

Regional Greenhouse Gas Initiative (RGGI) is the maximum mandatory Emissions Trading Scheme (ETS) for trading by participating countries of Eastern and Central North Atlantic. Initially RGGI started with CO_2 emissions from power plants with 25MW or larger generating capacity (RGGI 2008). The goal of RGGI is to reduce growth in CO_2 emissions resulting from the energy sector by 10 per cent by 2018 (Aldy & Stavins 2012 ; RGGI 2008). Alberta in Canada has created a carbon system, and is the first jurisdiction in North America to create a multi-sector regulatory-based demand for carbon reductions. Alberta-based compensation allows companies who need to further reduce their emissions to compensate other Albertan sectors (that have reduced their emissions voluntarily) by purchasing credits (Bolechowsky & Eng 2009). Independent third party verification is a mandatory requirement for Alberta-based offsets, with the relevant requirements set forth in the regulations for specified gas emitters in 2007, and technical guidance necessary to complete emissions reports (Environment 2009).

Australia has the largest emissions per capita in the industrialised world (Figure 2.3). Therefore, this country needs more accurate ways to reduce its emissions.

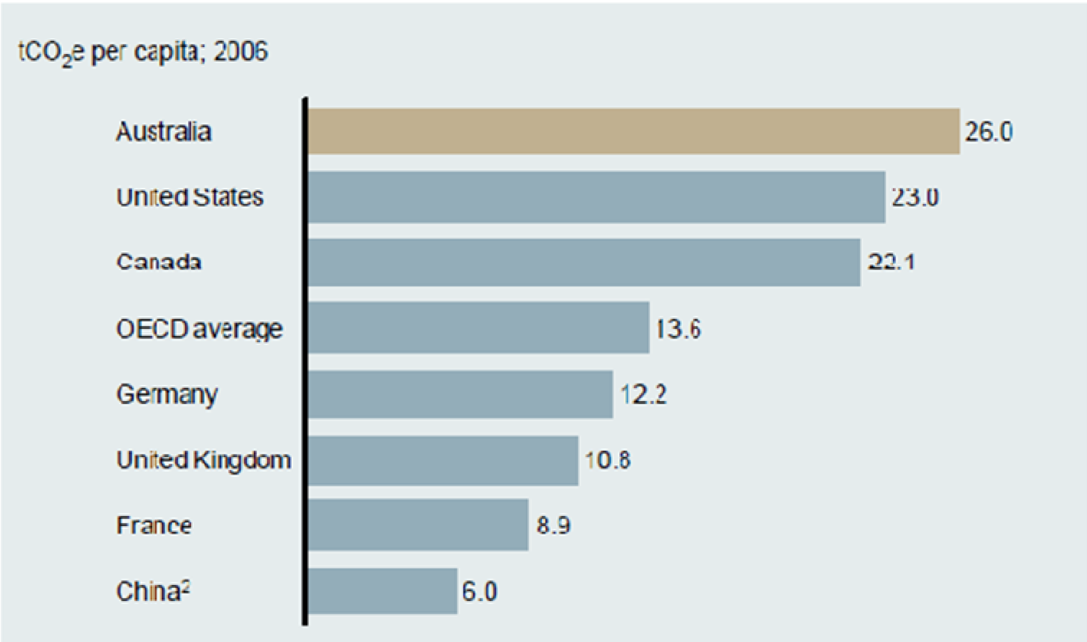

Figure 2.3 Greenhouse gas emissions per capita 2006
Source: (LCGPA 2010)

The National Greenhouse and Energy Report Act (NGERA) was passed in 2007. It aims to reduce carbon pollution and is supported by the Australian Government. NGERA is part of a pioneering strategy by the Australian Government to reduce carbon emissions to achieve a national rate of 60% from 2000 levels by 2050

(NGERA 2009). Therefore, the Department of Climate Change continues to develop and refine the task of ensuring Australia moves closer to the levels set.

The NGER Act makes it mandatory for the largest emitters above the limits of the energy standard in the Act to report annually from 2009 on GHG emissions, energy production, and energy consumption (NGERA 2009). In the same year, the Department of Climate Change issued a draft of the National Greenhouse Energy Reporting (audit) that estimated global warming and included an amendment to national energy reporting regulations (NGER) for public consultation (NGERA 2009). Mandatory reporting of GHG emissions is designed to monitor the impact of carbon pollution. Sectoral analysis may require detailed disaggregation into many sectors.

In spite of the importance of the power sector and its contribution to the achievement of effective development programs, the sector's negative impacts on the environment include local effects on air, water, soil and the emission of GHGs. This sector accounts for 25% of global GHG emissions that contribute to the phenomenon of climate change (Baumert et al. 2005; BCASF 2007). In addition, the emissions from the sector has been shown to effect local air quality and public health (Economic & Asia 2001). The sector could provide the most significant abatement potential by improving efficiency at generator plants, capturing and storing emissions, cogeneration, and renewable energy generation—these are some of the most significant abatement options being investigated (EPAQ 2008). Both households and industrial sectors consume energy, but the latter also emits GHGs via its processes. Thus, in Australia the power generation sector contributes 51.4% of GHGs emissions in CO_2 equivalents (PR 2010). Current emissions of CO_2 from Australia's grid-connected electricity generation sector are nearly 190 million tons per year with average emissions intensity of about 0.9 tons/MWhour (t/MWh) (Chattopadhyay 2010). Any abatement interventions here both in generation and consumption of energy could provide significant economic and environment benefits. Residential and commercial buildings are important areas for saving energy and emissions reduction.

The building sector can be split into residential and commercial, and accounts for 15.3% of international GHG emissions (Baumert et al. 2005). This is made up of 9.9% from commercial buildings and 5.4% from residential. The building sector represents a very small portion of the energy sector emissions and a slightly larger portion of the waste sector emissions. There is, however, a significant opportunity for the building sector to provide opportunities for improvements in construction practices that will result in emissions abatement in other sectors (EPAQ 2008). For instance, improvements in more energy efficient buildings will result in a decrease in energy demand and consumption in most countries.

The United States and the European Union were the two largest emitters of carbon dioxide in 2004 (Baumert et al. 2005), with about 2 $GtCO_2$ and 1.2 $GtCO_2$ emitted from each respectively. Emissions from the building sector varies greatly between countries, with a major association between emissions and the level of socioeconomic improvement in the region (Lazarowicz 2009).

It is expected that emissions from buildings would be direct and indirect. These emissions are likely to grow from about 9 $GtCO_2$ in 2006 to 12 $GtCO_2$ in 2030, an increase of 40% between 2006 and 2030, which represents about 15% of the total increase in global emissions by 2030 (Lazarowicz 2009; Perez-Lombard et al. 2008; Shiel 2009). Non-OECD States are responsible for 88% of the total increase in emissions at world level; new buildings in most of these areas in the coming decades will also be constructed. It is expected that non-OECD emissions from buildings will rise by 2.4% per year, while emissions in OECD states will rise by only 0.4% per year between 2006 and 2030 (Lazarowicz 2009; Perez-Lombard et al. 2008).

Implementation of a carbon emission trading system is also high on the agenda of the Australia government. The building sector is in favour of emission trading (for example, to be able to trade emissions with other industries), and there is a feeling that this would be more effective (a gain in both monetary value and sustainability) for the industry (Chaabane et al. 2012). Energy consumption has increased in residential and commercial sectors and their services in Australia by 2.2% in 2007-08 (Schultz 2009). In 2005, the commercial and services sector contributed to 10% or 56Mt CO_2e from GHG emissions in Australia. The residential sector also increased emissions, though less rapidly, due to occupants' increasing use of such devices as energy-efficient air conditioning. In 2005, the residential sector contributed 13% or 74Mt CO_2e of GHGs to Australian emissions (McKnoulty 2009). Figure 2.4 illustrates the growth in the building sector's energy use during the period 1973–74 through to 2003–04.

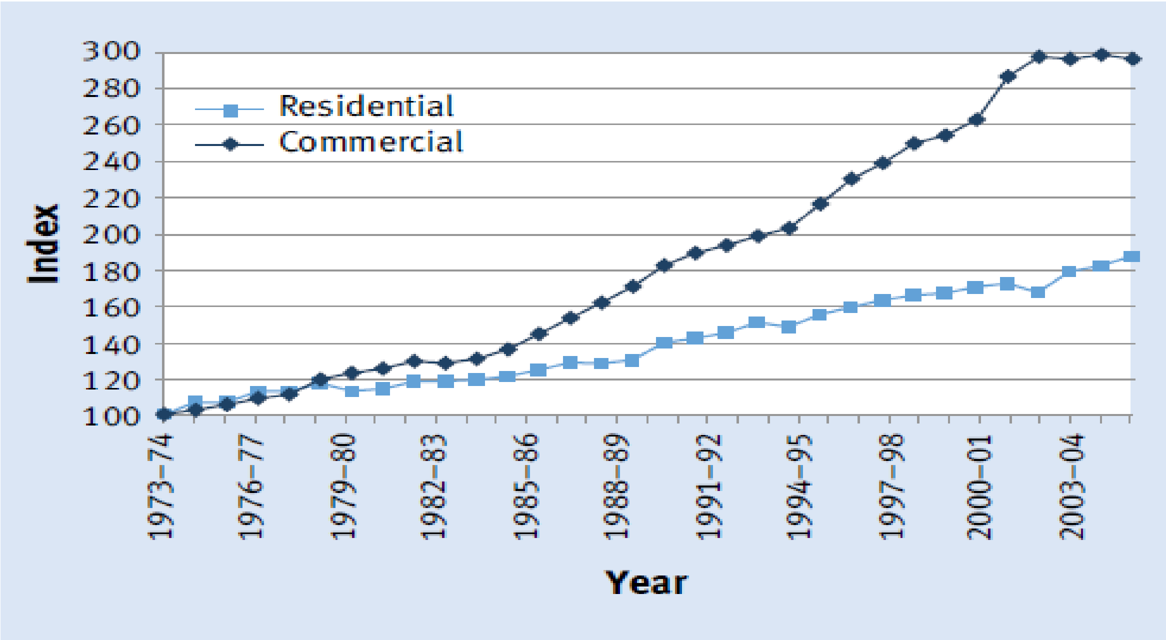

Figure 2.4 Growth in energy use in building sector 1973/74 through to 2003/04

Source: (McKnoulty 2009).

A study of climate change identified that the proposed Carbon Pollution Reduction Scheme (CPRS) could help lower emission levels (Pezzey et al. 2010). NGERA (2009) states there is significant unexploited potential for better energy efficiency in the building sector for GHG reductions of between 57 Mt CO_2e to 66 Mt CO_2e by 2030. Price signals have been estimated for expected GHG reduction in the building sector (Figure 2.5) (NGERA 2009). As a consequence of the CPRS price signal, the building sector will, on average, reduce emissions by an expected 8 Mt CO_2e a year (approximately 3-4% of the sector's total emissions each year in the BAU or baseline projection).

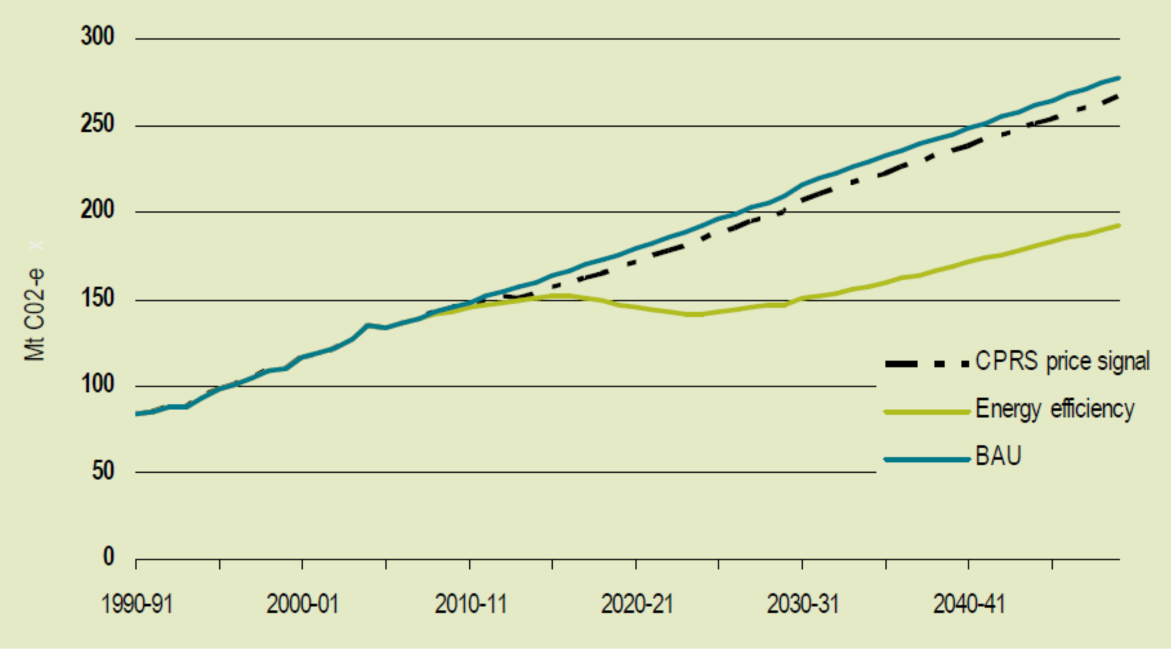

Figure 2.5 GHG Emissions in the building sector
Source: (NGERA 2009).

Great opportunities exist to reduce (cost-effectively) GHG emissions from buildings (Shiel 2009). It involves better insulated and designed buildings that create lower consumption of energy via efficiency in lighting, lower heating and cooling energy demand, the replacement of gas with solar power and biomass in space and water heating, application of standards of efficiency in household appliances such as air-conditioners and the replacement of biomass for traditional cooking and heating gas in developing countries (ürge-Vorsatz et al. 2007; Wagner et al. 2012). In addition, opportunities for mitigation increase from behaviour changes to lowering energy consumption by users of buildings, particularly in developed countries and several sector of societies in advanced developing countries (Lazarowicz 2009; Mark Levine & Ürge-Vorsatz 2008). Abatement cost curves of carbon reduction for the domestic sector show that some measures will be very effective in reducing emissions of CO_2 and have demonstrated to be cost-effective for different stakeholders (Kellett 2007; Weiner 2009). Therefore, the building sector could play a significant role in reducing GHG emissions with little or no cost abatement.

In Australia, the carbon price started at $23 per tonne in 2012-13 (Australia Government 2012; Chapple et al. 2013; Victoria 2011). In each of the following two years it was expected to rise in line with inflation to $24.15 in 2013-14. Organisations will be motivated to cut their carbon pollution bills by reducing their pollution production. A carbon price encourages businesses to look for ways to reduce their carbon pollution and encourages the development of clean energy technologies (BCASF 2007). Therefore, marginal abatement may be a useful way to help sectors and firms to reduce their GHG emissions (Almihoub et al. 2013a). It is possible to say that tools of accounting could provide effective financial reporting and may provide a method to help in the emissions reduction arena (Zhang 1998).

2.4 Accounting tools and methods

2.4.1 Conventional accounting

Traditionally, accounting consists of two elements: financial accounting and management accounting. Financial accounting is designed to provide an analysis of financial performance to guide the decision-making process on investments and performance management and also to support the information needs of external stakeholders (IFAC 2005; Petcharat & Mula 2010a; UNDSD 2001c). Financial accounting has been designed to impose systematic discipline on an organisation's data. On the other hand, management accounting, to a large extent, is used for decision making internally to measure the cost of inputs (materials and labour), while addressing all other cost overheads. Environmental costs have traditionally been addressed in management accounting as overhead costs and, thus, have been hidden for production and service operations (Hill et al. 2006). Accounting involves encouraging the adoption of standards of measurement in environmental data (Ascui & Lovell 2011). It also encourages the development of comprehensive and harmonious data sets over time that may facilitate sector, national and global comparisons (Alfieri & Olsen 2007). It is also used to measure accounting, business management and performance by the introduction of the Activity Based Costing (ABC) method.

2.4.2 Activity Based Costing

Berry (2005) states that management accounting provides companies with a way to create cost information to support business decision-making in every facet of business management, planning, and control to meet business objectives. In addition, management accounting has been used to measure business performance management through the introduction of Activity Based Costing (ABC) to capture the full costs of products and provide information on costs for internal decisions on investment (Armstrong 2006). ABC makes the distribution of costs to activities to support the most accurate pricing of products and services. ABC can play an important role in cost analysis, identification and allocation. Currently, ABC is developing in terms of green accounting and environmental accounting to develop estimating methods to reduce the negative impacts on the environment and ecosystems (Capusneanu 2009). Firms have adopted ABC with respect to the application of the cost of distribution and analysis. Thus, ABC could help firms increase their understanding of sustainability and how to develop ways to incorporate costs of environmental activities into products and service.

Understanding the factors affecting cost and cost allocation in accordance with theoretical foundations is the underlying principle of ABC. The importance of ABC is that it enhances the understanding of organisation processes associated with every product (UNDSD 2001b). ABC improves internal cost calculations through the allocation of costs that are commonly found in public accounts of activities of contaminated products, and is determined by quantitative assessment across a product's lifecycle (Wahyuni 2009).

Quantitative lifecycle assessment of environmental accounting systems requires a combination of quantitative value of environmental impacts associated with a project (De Beer & Friend 2006). Assessment could be at any one of three points. The first point is when developing a list of energy-related material inputs and environmental data; followed by assessing the environmental and social impacts associated with specific inputs and releases; and, finally, interpreting results to make informed decisions. Together, a quantitative life cycle assessment and an environmental accounting system provide an overview of environmental impacts of a project and a more accurate picture of the true environmental trade-offs, with associated financial implications, in the selection of product and process (Bowen & Wittneben 2011; Environmental Protection Agency 2001).

The total cost assessment using an environmental accounting system includes data of environmental life cycle assessment considered as part of the product or process evaluations (Norris 2001). Environmental accounting systems have the ability to assess the full life-cycle in question, and to consider all environmental and social aspects from the extraction of raw materials stage to the end of life of the product or process (Beer 2005). It underpins the understanding of health costs, environmental and human impacts of a project, which represent both internal and external costs (Little 2000).

2.4.3 Internalities and externalities

The global economy operates under the pressure of market forces that, until recently, have not complied with environmental principles. Before global environmental awareness, prices included traditional costing from accounting information that was built from an economic sense, without recognising the impact on the environment. After the impact of global environmental awareness, decision-makers were forced to view and include costing aspects that pertain to different global environmental systems (Bolinger et al. 2006).

Australia and Japan have experience in the implementation of environmental impact reduction, which is lowering the exploitation of their natural environment (Dascalu et al. 2010). During their experiences, they aimed for inclusion of external factors becoming internalised cost to achieve benefits which otherwise would not have been noticed or accounted for during the environmental balance of corporate governance. This allows companies to include considerations in the decision-making process that could enhance profitability (Guşe et al. 2010). It leads to ensuring the survival of an organisation in the future by understanding the potential responsibility and risk scenarios (Gale & Stokoe 2001; Guşe et al. 2010). In addition, organisations would be able to inform stakeholders on environmental and health impacts of economic activities of their organisation (Gale & Stokoe 2001; Guşe et al. 2010).

The externally-generated cost estimates are from environmental damage caused by an organisation during its activities in a specific location (Bockel et al. 2012; Dascalu et al. 2010). From a standpoint of economic theory, this approach estimates the cost of damage and the value of damage (to health) for those who bear the damage. The approach uses the value of the cost of damage from their loss of ability to estimate external costs. However, if companies measure reductions in environmental damage as far as 'optimal' (i.e. the extent to which they reduce the total cost of internal and external) then the marginal cost of external factors (the additional costs of the last unit and the damage) is equal to the cost of internal margins. On this basis, in some cases, marginal external costs can be equal to the marginal internal costs and estimated accordingly. This technique is called 'internalising the cost of control approach' (Guşe et al. 2010).

Accounting concerns for external costs in practice are increasingly using 'shadow prices' (a monetary unit for each tonne of greenhouse gas emissions) in capital budgeting decisions by companies (Dascalu et al. 2010; Gale & Stokoe 2001) . This reflects the view that although there are currently no such costs imposed on companies, it is likely that they will be in the future (Gale 2001; Jaffe et al. 2005).

It may be more practical and realistic for a company to take into account that external costs as internal costs are imminent. In other words, it can be assumed that the end of each category of external costs will be reflected in internal costs (Figge & Hahn 2004). Dascalu et al. (2010) state that external costs become internal costs and can increase from zero (when the costs are purely external) to amounts that can meet or even exceed the amounts of the initial external cost. Therefore, instead of accounting for external costs directly and immediately, external costs can have different configurations to be included in internal costs (i.e. external costs become internal costs). Formations of future time costs still have implications for current capital budgets and other relevant resolutions that include environmental accounting (Uno & Bartelmus 1998). Therefore, it is vital to apply environmental accounting in the contemporary workplace.

Environmental accounting is used to measure and report on allocation of environmental resources, costs, expenses and risks of different industrial groups to departments and specific projects, activities, or processes (Dascalu et al. 2010). With respect to increasing the base of environmental accounting, there are three techniques considered important: Total Cost Accounting (TCA), Full Cost Assessment (FCA), and Life Cycle Analysis (LCA). These are in the context of an ABC system that is designed to be a technique aimed at the economic analysis of a business's indirect costs (Dascalu et al. 2010; Gluch & Baumann 2004).

TCA refers to the analysis of long-term, comprehensive financial analysis for the full range of costs and savings for investment (Gluch & Baumann 2004). The general framework of the TCA technique represents an approach to an expanded traditional financial analysis (Dascalu et al. 2010). It is a tool for the preparation of feasibility studies that facilitate the identification and analysis of project costs and internal savings. TCA builds on the traditional models of cost accounting by including financial costs of direct and indirect costs recognised, units recognised (including costs of compliance in the future), penalties and fines, the launch of responses, treatments, and the time value of money. These costs are also sources of great concern in accounting models (Lovell & MacKenzie 2011). Traditional full cost environmental accounting (FCEA) considers the identification, evaluation and distribution of traditional cost and organisation sustainability (Dascalu et al. 2010;

Frame & Cavanagh 2009). From a social perspective, environmental accounting includes monitoring global performance; therefore, monitoring global performance broadens FCA (Bennett et al. 1999; Dascalu et al. 2010). Environmental accounting is recognised by professionals and academics. It includes traditional costs, as well as the internal and external costs socially borne by society (Guşe et al. 2010). This approach provides an opportunity to take into account external costs that may reflect real marginal costs.

Life Cycle External Costs Assessment (LCECA) attempts to impose costs of the life cycle model for estimating and linking, as well as implications of these costs in all life cycle stages of the product (Plesch 2003). LCECA aims to identify various external factors. This involves each stage of a product's life cycle to determine the relationship between them. The assessment includes total cost of a product and costs of any developments in the life cycle model. The results from the assessment are compared to an existing product with their alternatives and the effects of external factors in the environmental design of products (Dascalu et al. 2007). Therefore, to maintain the environment, organisations need to incorporate accounting sustainability.

2.4.4 Sustainability accounting

Accounting has developed the word 'sustainability' as the basis of measuring sustainable development of business in the form of environmental and social performance (Jasch & Stasiskiene 2005). Sustainability accounting provides firms with business tools to manage environmental and social costs, as well as offering information on the costs of business for decision-making processes and detection of unsustainable practices (UNDSD 2001a). Sustainability accounting attempts to maintain a balance between human activities and ecological patterns to keep development continuing in the long run (Berkel 2003). Sustainability accounting provides professionals with the various measures they need to improve long-term environmental and social performance. Thus, for the purpose of clarifying the benefits of sustainability accounting it is important to analyse the costs and benefits and present them to managers.

A study conducted in Australia indicates that cost–benefit analysis is an important accounting tool that managers can use to evaluate projected environmental impacts of various actions (Rubin et al. 2001; Wilmshurst & Frost 2001). Most companies do not identify the extent of their environmental costs since these costs are usually hidden in various broad administrative or manufacturing overhead accounts (Petcharat & Mula 2010b; Seidel & Thamhain 2002). Therefore, sustainability accounting can make accounting more appropriate for long term surrounding development.

Environmental accounting includes the identification, measurement and allocation of environmental costs, the integration of these costs into an industry, determination of environmental liabilities, if any, and, finally, communicating this information to a corporation's stakeholders as part of general financial and sustainability statements (Pramanik et al. 2007). Environmental accounting systems define, measure, analyse and convey information of environmental aspects of corporate activities (Burritt et al. 2002). Environmental accounting identifies environmental costs, capitalises costs, and measures liabilities (Pramanik et al. 2007). This approach helps firms and sectors to develop their performance environmentally and economically, as well as for disclosure of their emissions. Using an environmental management accounting approach can support development of more accurate information to support internal decisions on sustainability and emissions' reductions.

2.4.5 Environmental management accounting

Carbon accounting for emissions is practically and technically complex (Young 2010). Input–output analysis in particular identifies potential resource and energy savings. It is frequently the first step in an environmental audit process, and it could facilitate product invention and pollution preventing strategies, especially when it forms part of a product and/or process life cycle analysis (Jasch 1993). Input–output analysis can measure sustainability or unsustainability, thereby helping to provide a transparent account of physical flows into and out of a process, and enabling analysis of environmental impacts leading to eventual sustainability strategies (Gray 1994). Environmental management accounting (EMA) has emerged in recent decades as a reaction to the growth of environmental problems. Roman et al. (2006, p. 81) point out:

> EMA can be defined as the identification, collection, estimation, analysis, internal reporting, and use of materials and energy flow information, environmental cost information, and other cost information for both conventional and environmental decision-making within an organization.

Today, it is a broadly-used tool in balancing the interaction between economic, environment, social and technological factors in the development process to complete conditions for a sustainable environment (Erickson 2010). EMA collects data necessary to understand the marginal cost of implementing abatement. Scavone (2006) purports that firms are profit seeking and, thus, are always looking for a return on any investment, particularly from emission abatement interventions. Therefore, analysts need to find a range of options and choose those that will attain emission reductions contained in at least net present value (NPV) costs to account for time value of money.

2.4.6 Net present value and internal rate of return

Payback on investments is assessed by business and industry before a decision to implement is made. Process and equipment modifications, which can be implemented by many companies to reduce energy consumption, might be more costly than new capital projects (Hardisty 2009). In some cases, examining energy efficiency projects while considering carbon costs is not likely to provide internal rates of return that meet hurdle rates, and may then be rejected. As a result, many companies do not accept many worthwhile environmental projects. Although the profitability of these projects is positive (or cost-negative), they are not profitable enough to meet traditional internal rate of return (IRR) goals. Thus, environmental and social costs are almost always excluded (Hardisty & Ozdemiroglu 2005; Pearce & Warford 2001). NPV and IRR do not require assumptions about the discount rate to enhancing sustainability in business (Van Passel et al. 2010).

Calculating the costs of pollution control delivered by some measures requires consideration of cost profiles that extend over a number of years (Moran et al. 2008).

A consistent treatment of current alternatives involves deducting the cost of the treatment time. However, the discount rate can be significantly different by case in calculating the cost-effectiveness of mitigation options (Moran et al. 2008). The question then is what discount rate should be used. Should it be the social discount rate to reflect the preference of society to gain benefits now, deferring costs to a later time—which could be more appropriate when firms are dealing with environmental issues (Kesicki 2010a). There is no consensus in the literature on the preferable discount rate, but the social discount rate is purported to be mostly used (Sweeney & Weyant 2008b). A common social discount rate used is 3.5% (Kesicki 2010b; Kesicki & Strachan 2011). However, this rate can be modified to reflect other rates used to incorporate time preferences (e.g. the study of Greater Geelong used rates ranging from 12% to 38%) (ClimateWorks 2011), which should consider the opportunity cost of private capital.

Emission reduction measures will generally run over a period of years, making it necessary to estimate the age of capital equipment for the purpose of calculating the period of recovery-payback period (PP) (Wagner et al. 2012). This determines the time required to recover the capital invested in the project through annual returns. PP is an index which indicates the level of profitability of an investment. The best investment is one with the shortest recovery period. The PP rule is that the project should be acceptable if the project is less than PP from other projects; if the PP is higher than the PP of other projects, the project can be rejected (Ross et al. 1999). However, to be acceptable to an organisation, a positive NPV is sought from any investment in emission reduction technologies (Hardisty 2009). IRR and PP are indicators that help to choose the best investment, but they have some problems that can be found in the literature (e.g. Ross et al, 1999). An alternative tool that has been given some prominence in environment accounting literature most recently is the marginal cost approach.

2.5 Marginal abatement cost curves (MACCs)

MACCs emphasise on the direct costs related to emissions reductions. In general, this indicates investment cost, operation and maintenance cost, and fuel cost for reduction measures (Amman et al. 2009). Provided a MACC is built in a sound way, for example, taking into account system-wide relations and that the shortcomings are set out, it could be a preliminary guide to reduce costs and potential at a particular point in time. For years, economists have urged that if the MACC is established in a model that captures existing market distortions and interactions in the energy systems and the broader economy, it could provide valuable insights to decision makers regarding the presenting of a CO_2 tax (price based) and the presenting of a CO_2 permit system (quantity based)(Carlson et al. 2000; Kesicki & Strachan 2011). Technologically, MACC can also support in the context of research, development and deployment policies by providing insights into the marginal abatement cost of technologies and offer an indication about the necessary level of economic incentives or feed-in tariffs in order to allow a large scale deployment. Concerning command-and-control instruments, technology-explicit abatement cost curves provide guidance to decision makers on the maximum reduction potential and financial benefits of no-regret measures once market distortions have been overcome (Bréchet, T. & Jouvet, P.-A. 2009). MACC theory is an accounting approach used to present graphically, and to quantify investment performance of various energy and emissions reduction projects. The methodology ranks the different projects from the most cost effective on the left, to the least cost effective, while illustrating the total energy saving or CO_2 abated by each individual project.

Studies by McKinsey and Company (2007a) have developed a MACC for the global economy and for different nations including Australia, the USA, UK and Germany. National MACCs of this sort are necessarily at high levels, and concentrate on sectors of the economy. Overall, these MACCs disclose a common pattern of significantly available negative cost (net saving) of abatement opportunities (Enkvist et al. 2007). While these overall macro trends are generally instructive, national or sectoral MACCs are not particularly useful for decision making within particular industries and sectors, or for particular projects or investment decisions (Enkvist et al. 2007). However, MACCs related to firms in each sector may provide advantages (Vijay et al. 2010). Sectoral analysis may require detailed disaggregation into many sectors.

2.5.1 Marginal cost

Marginal cost (MC) is the change in total costs that arise when the quantity produced changes by one unit. In other words, the MC of an additional unit of output is the cost of the additional input needed to produce that output. More precisely, marginal cost is the derivative of total production costs with respect to the level of output (Sullivan & Sheffrin 2003). The MC approach is defined as the first derivative of the cost as a function of energy conservation or for practical causes; additional costs are compared to the benefits to define efficiency levels (Jakob 2006). It is also called incremental cost.

Narrowing the definition of abatement costs, enterprise cost explains the cost of an individual abatement alternative, which is assumed to have no large indirect economic impact on markets and prices (Ekins et al. 2011). It takes into account such things as the change of techniques in production factories, enhancement of efficiency, fuel switching, or the achievement of infrastructure changes. Cost measurement contains investment, operation, upkeep and fuel costs, as well as disposal (Hutton et al. 2007). In the technology cost accounts, a technology that has many implementations in diverse enterprises takes learning curves into account, as well as associated efficiencies and economies of scale (Ekins et al. 2011).

Typically, abatement cost data are collected at a micro-economic level and illustrates the costs of technical options for reducing a certain kind of pollution (Schwarzenegger 2005b). They are presented as cost functions (abatement cost curves). Such cost functions plot, for each kind of measure, the cost per unit of avoided pollutant against the volume of avoided pollutants. In applying such curves they mostly confirm the standard economic hypothesis of increasing marginal costs (Faber et al. 2011). However, exceptions mostly exist. In studies of CO_2 abatement costs it is often found that significant primary reductions can be obtained as negative costs (net savings), for example, by applying energy reduction measures that will enhance profitability (UN 2003).

Emissions scenarios give an indication of possible effects of mitigation policies (Van Vuuren et al. 2008). Emissions scenarios for climate change investigations are not anticipatory or predictive but reflect expert judgments regarding plausible future emissions depending on research into socioeconomic, environmental and technological trends represented in integrated assessment models (Moss et al. 2010). Industrial activities into pollution abatement capital expenditures and operating costs may include more than one of these categories of activities—treatment, recycling, disposal, and pollution prevention; and by three types—air emissions, water discharges, and solid wastes (Gallaher et al. 2008). Thus, abatement costs, accurate data collection, emissions scenarios and their applications are of critical importance in the development of emission reduction strategies. Consequently, a contemporary marginal cost approach can be applied in the form of a marginal abatement cost curve tool.

MACC is a function that shows the cost in terms of dollars per unit tonne of GHGs, which is associated with the final unit of reduced emission (Kuik et al. 2009). This last unit of emission abatement is measured in amounts of CO_2 equivalents (CO_2e) reduced. Just as the name suggests, a MACC enables one to analyse the cost of the final abated amount of carbon dioxide, as well as reveal the total costs associated with CO_2 abatement by integrating the whole cost curve (van Odijk et al. 2012). According to the Environmental Protection Agency (2008, p. 10):

> The marginal abatement cost curve is an evidence-based tool available to policy makers to assess the potential for greenhouse gas abatement in a region and/ or sector of the economy according to the cost of abatement. It is derived by generating expectations about the potential for abatement relative to a reference case. Construction of the marginal abatement cost curve involves assessing individual initiatives for their abatement potential and cost, and arranging these initiatives in graphical format from least cost to highest cost order. Importantly, the profile of initiatives considered is crucial: invoking some abatement options will impact the abatement potential and costs of others (for example, improvements in electricity efficiency in consumption will reduce the abatement potential of electricity supply initiatives).

A MACC meta-analysis was undertaken of up-to-date studies into costs of GHGs alleviation policies. It found that marginal abatement costs of tough long-term targets that were considered by the European Commission are frozen and very uncertain, but may surpass costs that have been suggested by present policy assessments (Kuik et al. 2009). McKinsey (2007a) developed MACCs for the international economy and for several countries including Australia, the USA, the UK and Germany (Hardisty 2009). In addition, the concept of a MACC is an approach available to an economy to achieve increasing levels of emission reductions. These are valuable tools in understanding emissions trading, driving forecasts of carbon allowance prices, prioritizing investment opportunities, and shaping policy discussions. However, there are a number of approaches used to create MACCs.

2.5.2 Different approaches to MACCs

MACCs can be determined in many ways. Firstly, expert-based approaches are developed from experts' assumptions, which are derived from the respective costs of abatement measures, the creation of CO_2 emissions and the potential of abatement measures in reducing CO_2 emissions. For instance, the cost of abatement measures such as incorporation of new technologies and improvements in efficiencies, as well as fuel switch, can be considered when using this approach (Kesicki 2010a). Based on the various assumptions made, abatement measures are openly arranged from the cheapest to the most expensive. With this arrangement, there is an explicit representation of the associated costs of reducing additional emissions (Hogg et al. 2008).

In 1970, the concept of an expert-based approach was initially employed in reducing industrial consumption of electricity and crude oil (Kesicki 2010b). In recent years, this MACC approach has attracted a great deal of attention due to national studies published by McKinsey & Company (Kesicki 2010a). McKinsey & Company managed to develop two expert-based curves—country based and global. Through the process of differentiation, expert-based curves can estimate abatement curves. However, this relies highly on discount rates, subsidies and taxes. To reflect the societal perspectives in abatement measures over a specific period of time, reduced discount rates (i.e. 3.5%) are normally used (Pye et al. 2008). However, these abatement cost curves normally consider higher rates of interest, taxes and subsidies in order to come up with the right measure of costs associated with investment decisions. Similarly, there is integration of specific discount rates associated with higher technologies (Kesicki & Strachan 2011). A MACC could reveal financial constraints that face households, as well as the uncertainties that can be linked to investment decisions geared towards reducing the cost of GHG emissions (Kockelman et al. 2009).

McKinsey and Company (2007a) developed a MACC for the global economy and for different nations including Australia, the USA, UK and Germany. National MACCs of this sort are necessarily at high levels, and concentrate on sectors of the economy. Overall, these MACCs disclose a common pattern of significantly available negative cost (net saving) of abatement opportunities (Enkvist et al. 2007). While these overall macro trends are generally instructive, national or sectoral MACCs are not particularly useful for decision making within particular industries and sectors, or for particular projects or investment decisions (Enkvist et al. 2007). However, MACCs related to firms in each sector may provide advantages (Vijay et al. 2010).

One major advantage of the MACC approach is that it offers a great deal of ease of understanding (van Odijk et al. 2012). Generally, its marginal costs, as well as abatement potential of various measures, can be linked to a single mitigation option without any ambiguity (Farber 2012). In addition, technological details that are considered in this approach can be extensive (Wang et al. 2009). However, this will depend on developments in research studies (De Vries et al. 2007). Basically, a MACC developed using an expert-based approach reveals the technological capacity of measures used in abating GHG emissions (Watkiss & Hunt 2011). Since MACCs developed using this approach highly depend on technical judgments, their assessments require integration of technology-specific subsidy distortions as well as existing taxes (Kesicki 2010a). Nonetheless, a MACC developed using this approach does not take into account behavioural aspects or barriers associated with an institution and its implementation. As a result, this appears to leave this approach with higher abatement potentials compared to other approaches. By improving energy efficiency, it is argued that behavioural aspects are sometimes catered for by "adjusting the reference demand" (Kesicki 2010d, p. 5).

Based on the concept of 'probability of realisation', a technology-based approach can exclude promising technologies from the future since it primarily focuses on commonly existing technologies. Similarly, the MACC approach makes it impossible to have an accumulated abatement cost from various sectors such as transport, residential or industrial that contribute to GHG emissions (Legge & Scott 2009). This difficulty is quite common due to the fact that mitigation costs are usually implemented by different experts (decision-makers) with different perspectives. In addition, baseline assumptions in this approach have possibilities of high inconsistencies as different experts may have different references to support their perspectives. It implies that for proper calculation of marginal costs associated with abatement potential, a reference aspect of the development must be considered (Murphy & Jaccard 2011). However, only those that could offer cheaper abatement potentials should be adopted. Most significant in this MACC approach is non-consideration of various interaction types. It should be noted that MACCs developed by this approach cannot capture interactions that occur between behavioural aspects, economy or abatement measures. On the other hand, there is a possibility of reducing the abatement cost due to the effects of technology learning that occurs before and after a given period of time considered in a MACC (Kesicki 2010a). Moreover, this approach presents many difficulties in assessing single-based measures.

A model-derived MACC approach is another widely-used method (Watkiss & Hunt 2011). This approach uses various energy models and techniques. In this respect, two major MACC models derived are top-down models and bottom-up models, the former being economy-oriented while the latter is engineering-oriented (Kesicki 2010c). Historically, policy-makers have encountered many difficulties when choosing between models for evaluation of policies to influence technology choices of energy-related intervention (Jaccard et al. 2003).

An abatement curve is developed in both bottom-up and top-down models by summarising the cost of emissions and (CO_2e). This carbon price can result from either of the two sources: "runs with different strict emission limits" or from the GHG emissions coming from various carbon dioxide prices (Kesicki 2010d, p. 6). Unlike the expert-based MACC approach, the model-based abatement curve does not consider or show any technical information. The bottom-up approach is highly dependent on technological information. Bottom-up models present how changes in energy efficiency, fuel and emissions control tools may impact infrastructure and energy use, and their subsequent environmental impact (Morris et al. 2002).

It is generally assumed that technologies that provide energy services themselves to be perfect substitutes except for the differences in the expected financial costs, energy use and emissions (Jaccard & Dennis 2006; Sathaye & Murtishaw 2004). When financial costs are converted in different time periods to present value using a social discount rate, many of the techniques available appear to be profitable or relatively just a little more expensive than the existing stocks of equipment and buildings (Jaccard & Dennis 2006). Bottom-up models appear in many cases as a useful method, which can be profitable or improve the environment at a low cost if these low-emission technologies were to achieve market dominance (Bailie et al.

2009). Traditional bottom-up models are partial equilibrium models with a focus on optimization of costs in the energy sector or sub-sector specifically, but dispense with links between these sectors and the wider economy (Kanudia & Loulou 1999).

A bottom-up model sometimes exhibits lower MACC values compared to a top-down approach due to the fact that the approach does not incorporate feedback impacts from both macro- and micro-economic elements (Pye et al. 2008). Other than the model's structure, this approach is associated with assumptions on key economic drivers such as technology transfer, disaggregation (sectoral and regional), emission levels and trade across borders (Böhringer & Rutherford 2008). Apart from the aforementioned weaknesses, it should be remembered that a MACC derived from a bottom-up approach has direct abatement costs and faces a high risk of penny-switching, where minor changes in costs lead to large shifts in the energy system and does not consider rebound impacts of abatement measures (Kesicki 2010a). This highly contrasts with top-down models that try to consider internal economic reactions in the entire economy (Böhringer & Rutherford 2008). Logically, this would give limited information on how the economy could be in the future. Based on this fact, a MACC based on a bottom-up approach would be quite inefficient in revealing the actual marginal abatement cost, thus bringing an accusation of overestimating the core elements of a MACC. One example of a MACC developed from the concept of a bottom-up model is Targets Image Energy Regional (TIMER) model. It features support of bottom-up models to yield a MACC with a balanced level of aggregation and concentrates on dynamic energy issues such as fossil-fuel depletion, inertia, trade and learning by doing (Kesicki 2010a). Not only do bottom-up models have a place in energy and emissions reductions, but top-down models are also considered important.

Alternatively, a top-down analysis estimates total relationships between relative costs and market shares of energy and other inputs for the economy linked to economic sectoral and macro output in a wider context for balance. From the top-down model, the estimated parameters characterise the response of the model to the policy, including the elasticity of substitution and improved efficiency of energy use in autonomous areas. It can also estimate historical data if the previous data is available. If the historical data is not available, estimations can be obtained from other sources (Bataille et al. 2006). The top-down model estimates parameters of real market data, with higher energy prices and consumption change from a historical perspective; it is designed to reveal the actual preferences of consumers and businesses. Because it requires technological details, the top-down model of simulation has been restricted in fiscal policies, which increases the relative cost of inputs to a particular share. The necessary signal to achieve the fiscal target for reducing emissions is due to the cost implied. This includes intangible costs related to risks of new technologies and risks of long-recovery technology. Preferences for the attributes of one technology over its rival are also very important for any emissions reduction. Thus, estimates of cost to achieve environmental goals using top-down models are usually higher, and almost never less, than a bottom-up estimate (Rivers & Jaccard 2006).

The top-down approach is also subject to criticism because it might not be useful for policy makers (Chattopadhyay 2010). If the top-down approach produces parameters for the imaging of technological change, the elasticity of substitution and autonomous energy efficiency improvement is the amount of data compiled historically. There is no guarantee that these parameter values will still be valid in the future under different policies to improve the environment (Grubb, M. et al. 2002). Growing concern about this issue has led to some top-down models exploring methods of treatment of technological change using the bottom-up approach. However, to date, there has been limited success in linking real-world evidence to estimations of parameters of technological change in these models (Löschel 2002). Other difficulties are restrictions imposed on the development of policy-makers' understanding of technology. as well as policies in the form of specifically building tax exemptions, subsidies, regulations, and media programs (Kesicki 2010d). Because traditional top-down models represent technological change as a phenomenon, the overall abstract, this approach only helps policy makers to assess the level of fiscal policies such as taxes and tradable permits on the economy.

Top-down models capture government details, supply levels of inputs, end users, product flows, producing sectors, and money and services that exist in the entire economy (Böhringer & Rutherford 2008). It can thus be seen as a model with an equilibrium approach to MACC development since it integrates economic data in establishing numeric values of final prices that would influence both demand and supply. Unlike bottom-up approaches, top-down models are commonly used for computations of MACCs (Böhringer & Rutherford 2008). The use of these two approaches ensures that interactions that occur between abatement measures are significantly considered. It is also possible for one approach to complement the inconsistencies exhibited in the other since they adopt a systems approach in generating a MACC (Böhringer & Rutherford 2008). As a result, this makes bottom-up and top-down approaches powerful MACC approaches that reveal uncertainty associated with various abatement measures (Jackson 1991).

While it is impossible for any model of policy to be completely accurate in its representation of the current circumstances or description of the dynamics of the future, the above discussion refers to standards that can judge the ability of the model to be more useful for policy makers seeking to induce technological change (Rivers & Jaccard 2006). Policy-makers require models that can be a realistic assessment of the combined effects of policies ranging from the economy to broad technology-specific measures (Metcalfe 1995). Thus, instruments will include the potential for command and control systems, as well as financial charges and subsidies (Stavins 2007). To do so, models should include a clear representation of technologies that compete to provide services in all economic sectors. Also, they should mimic the way in which consumers, companies and producers choose between these techniques to reflect the close balance and feedback in the real world. This could achieve balance between energy and technology, and overall structure and performance of the economy (Tester 2005).

Since none of the traditional models (bottom-up or top-down) are good performers in relation to these standards, efforts have been made to develop a hybrid that combines the essential elements of both models (Murphy et al. 2007; Schaefer & Jacoby 2005). Thus, some models integrate supply and demand for energy, and even include some of the interactions between the energy system and economy as a whole. Developments with the optimal model MARKAL is worth considering. MARKAL is applied on a large scale from bottom-up, is dynamic, and is a mostly linear programming model originally developed by the Energy Technology Systems Analysis for International Energy Agency (Schaefer & Jacoby 2005). As a result, it has contributed to this framework (the framework of models for energy planning- nationally and locally) and developed strategies for carbon mitigation (Nystrom & Wene 1999; Seebregts et al. 2001; Worrell et al. 2004). There is a new type of this form called SAGE (new MARKAL), designed for a degree of behavioural realism in the process of technology acquisition (Murphy et al. 2007) by consumers, producers and modelling, also myopia, including the representation of non-monetary costs that affect behaviour. On the other hand, some models include technical details, mostly in the energy supply sector (Bohringer & Loschel 2006), although others have made greater progress in their representation, including more details of other sectors (Schafer & Jacoby 2006). Unlike the expert-based approach, model-based approaches present few complications in combining various abatement curves from different sectors (Böhringer & Rutherford 2008), due to their reliance on societal perspectives. It is, therefore, concluded that a majority of expert-based weaknesses are addressed by model-driven approaches, and could be a useful methodology to develop a MACC at firm level, but the question of how to represent complex models and their output to decision makers remains a challenge.

2.5.3 Representations of MACCs

MACCs are becoming a standard tool for analysing price and number effects in carbon markets and are broadly used, for example, for analysing the integration of national trading systems (Anger 2008; Criqui et al. 1999; Ellerman & Decaux 1998 ; Stankeviciute et al. 2008). MACCs can be derived in numerous ways which are reflected in the differences across models (Flachsland et al. 2011). According to McKinsey & Company (2010a), the representation of a MAC-curve can be in the form of a bar chart or curve. Graphs can be positive or can exhibit negative and positive values. However, whichever representation method is used, there is little difficulty in reading them. For instance, in a bar chart every bar represents one option towards low carbon emissions with its width representing the abatement capacity relative to business as usual (BAU). The height of every bar also reveals the cost of abatement options, relative to BAU. In either line graph or bar chart, this cost is expressed in dollars/Euros/Cedis per unit tonne of GHG emission controlled or avoided. However, the sum of all bar-widths reveals the total abatement potential, while their total area reveals the marginal costs for the chosen direction—such as in Figures 2.6, 2.7 and 2.8. Bar charts are now more commonly used even though the method is still referred to as a MAC curve.

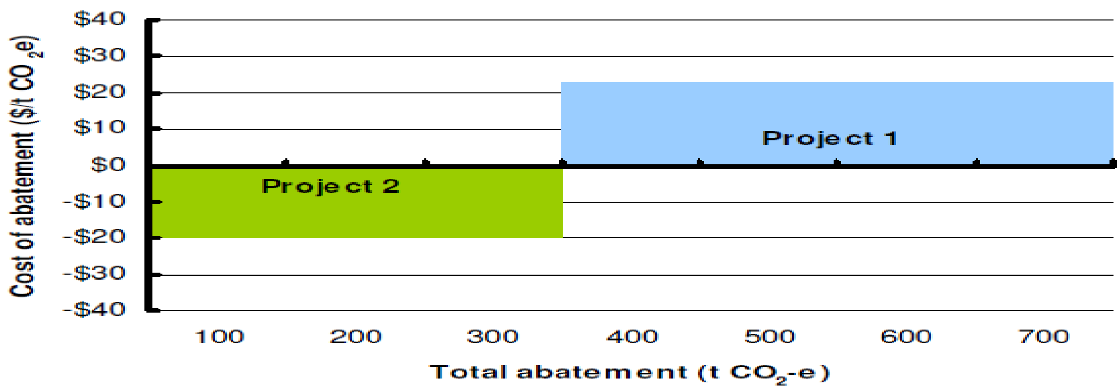

Figure 2.6 MACC for two projects

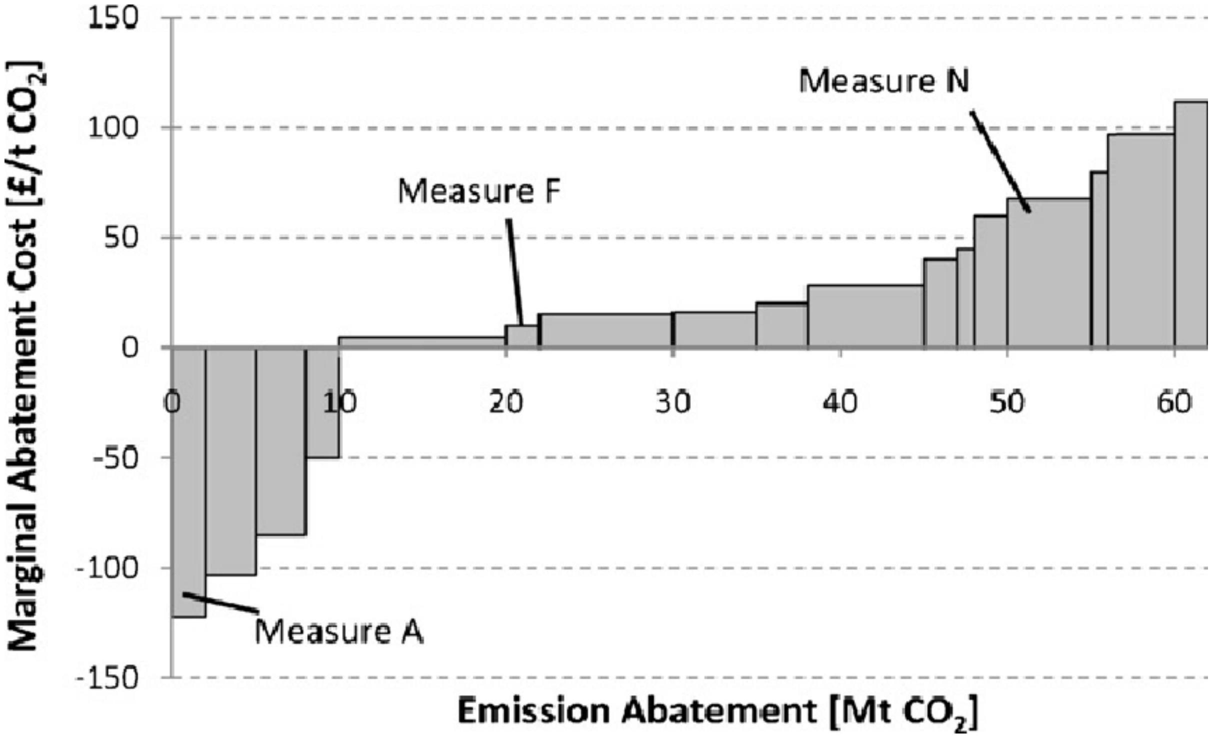

Figure 2.7 Sample marginal abatement cost curve
Source: (Kesicki & Strachan 2011)

2.5.4 MACC applications

MACCs have been applied by a number of researchers. Many economists, research institutes and consultancies have produced MACCs. Bloomberg New Energy Finance (Turner.G et al. 2010) and McKinsey & Company (2007a) have produced broad economy analyses of GHGs reductions for the United States.

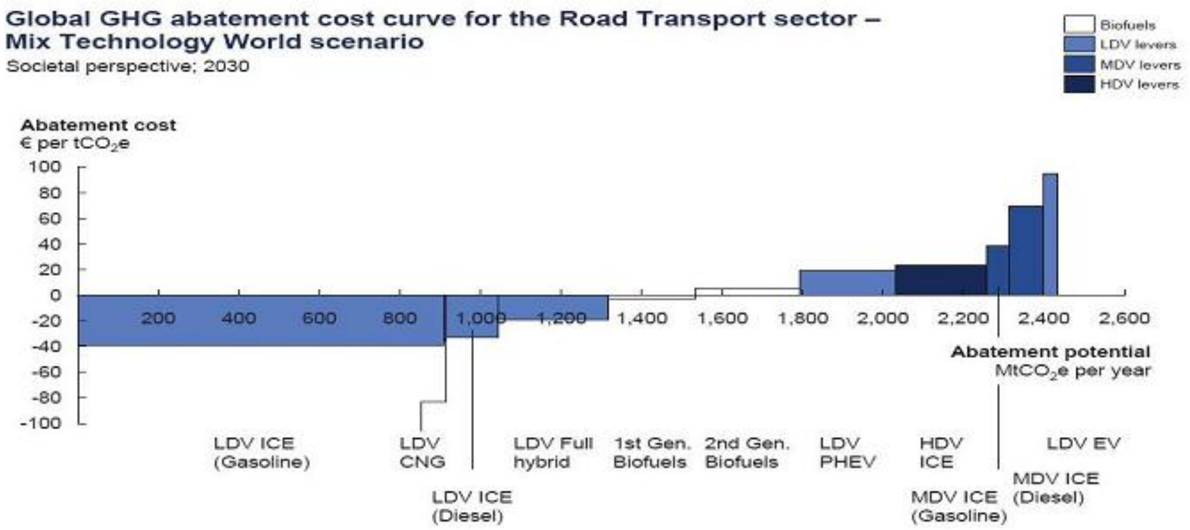

Figure 2.8 Global GHG MACC for transportation
Source: (Powell 2011)

ICF International (Schwarzenegger 2005a) produced a California-specific curve following AB-32 legislation (Sweeney & Weyant 2008a). The US Environmental Protection Agency has carried out work on a MACC for non-carbon dioxide emissions. Enter Data and LEPII-CNRS (France) produced MACCs with the POLES model for the 6 Kyoto Protocol gases. These curves have been used by various public and private sectors to assess carbon policies (Turner.G et al. 2010).

Normally, MACCs cover emissions reduction opportunities across some sectors in an economy including power, industry, waste, buildings, agriculture, transport and forestry. In the UK, MACCs have been widely used in both domestic and international environments in shaping climate change policies (DECC 2009). This implies that these curves have played a significant role in helping policy makers. In connection to this, the Committee on Climate Change, which was initiated to guide the UK on abating greenhouse effects, came up with MACCs for various applications in different areas. In this regard, the UK government used the concept of a MACC to introduce a carbon tax aimed at abating the use of fossil fuels in agricultural, commercial and industrial sectors (DECC 2009). Since their establishment, the use of MACCs has spread to quite a number of countries which use them to evaluate their climatic policies. For instance, this has been realised in France where model-based MACCs significantly contributed to the preliminary steps in evaluating abatement measures. Based on these curves, quota systems, renewable obligation and feed-in policies have been introduced to control the deployment process of technologies associated with the generation of electricity. However, it is reported that the majority of MACCs being used in the UK are technology-based (bottom-up).

Economically, MACCs have been used by the UK government to guide the potential of technical mitigations for energy (Markets 2010). It also uses these curves to forecast the future of energy sectors in terms of cost elements. Another economic application of MACCs is by carbon traders who use it to derive the supply function, which helps in modelling the fundamentals of carbon prices. Based on the decision making properties of MACCs, power companies have applied these concepts in guiding their long-term investment decisions based on the different efficiencies offered by generation choices of abatement measures (Smith et al. 2007). In recent work by McKinsey & Company (2007), it was realised that MACCs have been widely applied to evaluate how greenhouse gas emissions can be reduced.

Nowadays, MACCs have improved as a standard instrument to analyse the impacts of the Kyoto Protocol and emissions trading (Ellerman & Decaux 1998 ; Wassmann & Pathak 2007). The idea of a MACC has come from a company or factory level model of reducing emissions, but it is regularly used for assessing reduction costs for individual sectors of the economy, as well as certain regions (Klepper & Peterson 2004). Given (a) emissions of unwanted materials and (b) the availability of pollution control technology, use of marginal costs (shadow prices) to achieve a specific goal given a certain emission level of production is increasing (McKitrick 1999). Apart from technological adaptation there may also be structural changes that can overcome obstacles to emissions reduction. Many firms have used MACCs instead of net present value (NPV), which determines the present value of net costs by summing the discounted cash flows over the life of the option or project. MACCs present a complete picture of environmental costs and benefits, each option over the lifetime of capital employed (Almihoub et al. 2013c; Jorge et al. 2005). To exploit more and get further benefits of using MACCs, the following section examines explicit carbon pricing policy regimes that are currently in place.

2.5.5 Pricing carbon

Mitigation risk could be driven by growing pressure from all society's segments. Domestic and international efforts may attempt to prevent the worst damage caused by climate change such as significant reductions in emissions of GHGs (Sandor et al. 2002). Reductions in emissions are a massive challenge. According to IPCC (2007c), Stern (2007), Garnaut (2008) and Hardisty (2009) there is a global need to decarbonise by up 60 to 80 per cent by the year 2050 to give business a reasonable opportunity to avoid the worst effects of climate change. The size of this change means that it will put appropriate price signals in place to gradually increase the cost of carbon. Management provided by carbon tax on a large scale in one form or another is the main challenge for policymakers at all levels, in all sorts of businesses. Carbon-intensive processes will need to make deep changes to avoid large increases in costs, after-effects of competitiveness, profitability and organisational sustainability (Sandor et al. 2002). Providing a 'cap and trade' scheme also means that overall emissions are limited in preventing the expansion and growth in emissions (Parker 2009). Thus, organisations of all kinds need to develop strategies for growth and expansion of their operations within this new frontier.

Including management of carbon in the process of effective decision-making requires that there is a given carbon price (CP). CP can be embedded in the price during financial and economic analyses of projects; this is used to understand current and future effects of different investment decisions on capital (Hardisty 2009). However, there are many different methods to consider when evaluating carbon. One such method is market-based prices, which set plans for various trading, social value of the real damage of each additional tonne of GHG emissions emitted, by costing of the shade, and marginal costing of controlling pollution (Shobe & Burtraw 2012). Because of their importance each method will be considered in turn.

There are many kinds of emission reduction prices related to each domestic area that depend on different types of mitigation practices (Lee et al. 1996). Carbon pricing in one form has become common. In Europe, the prosperity of the carbon market was worth over US$24 billion in 2007, handling more than one billion tonnes equivalent of CO_2 (tCO_2e). The trading system in the European Union (emissions trading system) long-term phase 2 average price now stands at about US$ 20-25/tCO_2e (Hardisty 2009). Clean Development Mechanism (CDM), which was established under the Kyoto Protocol, traded more CO_2 equivalents in 2006 and is valued at more than US$15 billion (Hamilton et al. 2007). Other trading schemes, voluntary and orderly, began to appear worldwide (Hardisty 2009). In Alberta, Canada's oil and gas-producing province and home of the huge Athabasca tar sands reserves, the Canadian government announced there will be a new tax of $15/tonne on GHG exceeding reduction targets (Aldy & Stavins 2012 ; Hardisty 2009). Voluntary Chicago Climate Exchange has increased year after year since its inception. The Montreal Stock Exchange announced a similar voluntary market in Canada (Hardisty 2009). Carbon prices paid are also reducing carbon with mandatory renewable energy targets (MRETs) being developed by various governments around the world, national states, and at local levels (Kuwahata & Monroy 2011). While many USA states have their own major goals for renewable energy in place, full participation by the United States at the federal level could have a resounding impact on the way the rest of the planet approaches organising carbon reduction in the ensuing decades (Hardisty 2009; Speth 2009). Australian has set maximum GHGs thanks to the State and Commonwealth Governments MRETs, which came in to force in 2010 (Jotzo & Betz 2009). All of these measures impose increasing penalties in terms of direct financial costs to firms that emit large amounts of GHGs.

Although most global communities have agreed to reduce carbon emissions (Nordhaus & Yang 1996), there is a significant difference in carbon price between the current market-based systems (in the case of cap-and-trade) and carbon tax rates on the basis of real value of the damage caused by carbon emissions in the atmosphere (Metcalf 2009). The social cost of carbon reflects the value of the damage caused by each additional tonne of GHG emissions that is put into the atmosphere. These impacts are in terms of the likely effects expected on the global economy caused by global warming, rising sea levels, and weather-related events resulting in a decline in agricultural production, loss of biodiversity, and others (Hardisty 2009; Stern 2008). Carbon markets or taxes reflect only the cost of government policies that are imposed on emitters. This cost is likely to represent only a fraction of the true value of the damage (Metcalf 2009). Because emissions are linked to rising temperatures from atmospheric concentrations of GHGs, these gases are long-term. Thus, the total amount of GHGs in the atmosphere is directly related to the social cost of carbon, even to the extent that the higher the concentrations, the higher the social cost of carbon (Stern 2008).

It is often in the interests of individual organisations and sectors to educate consumers about the implications of responding to energy savings and emission reductions through changes to products and services (Dietz et al. 2009). There is a desire from consumers to obtain environmental benefits of products—but without paying more costs for these benefits in the short term. Public education is considered as the key to creating ‘willingness to pay’. The ability to create or identify emission reduction opportunities to different products and services is long term, but could ultimately lead to creating environmentally aware consumers (Kobos et al. 2006).
This aspect could be the subject of a consumer education campaign, although public education could decrease consumer demand of certain products and/or services as a result of changes in energy usage.

It is important to recognise the effects of climate change on communities and present strategies to deal with these effects (Wilkinson et al. 2009). Stern (2007) examined the economic effects on a community using expected impacts of climate change at the macroeconomic level. He has estimated what it would cost to take action to stabilize levels of GHGs in CO_2e less than 550 ppm (Hepburn & Stern 2008). To give the world a chance to avoid high temperatures above about 2°C, on average, it would cost about 1 per cent of global GDP each year (Stern 2008; Wilkinson et al. 2009). However, not acting to control the emissions—in other words to continue business as usual in the emissions path—will cost the global economy between 5 and 20 per cent of global output now and forever. Therefore, the fight against climate change is a strategy of pro-growth (Hardisty 2009).

Although emission reduction can boost profits, an increase in costing can have a negative effect on business (Smale et al. 2006). Stern (2007) did not address exactly how these results affect long-term business, investment decisions and business planning. Climate changes form risks, uncertainties and many opportunities for business as society increasingly demands to organise work and decrease emissions of

GHGs. If this takes the form of mandated goals that reduce carbon and market structures associated with them, some form of carbon tax is needed to be evaluated carefully and have clear economic value (Hardisty 2009). Costs and benefits from actions taken by companies to reduce emissions also need to be studied carefully as the cost of the carbon market (now in the order of US\$5-25/tCO_2e) ascends towards the social cost that Stern (2007) estimates at US\$85/tCO_2e, to get on the path of emissions as 'business as usual'. Additionally, it is worth mentioning that since the publication of the Stern Review, world GHG emissions have accelerated significantly (International Energy Agency 2007), suggesting that a similar analysis of the social cost of carbon made today will result in a higher social cost of carbon.

A shadow price of carbon and social discount rate could be used to evaluate some environmental projects (Hanley 1992). The United Kingdom's government identified the Shadow Price of Carbon (SPC) as one of the options to assess projects within the UK (DEFRA 2008). SPC is based on the realisation that one nation cannot be isolated in determining the course of global emissions. Based on the stability of global concentration of CO_2 in the atmosphere at 550 ppm, Stern (2007) calculated implicit social cost of carbon in the USA at \$30/tCO_2e. DEFRA (2003) developed a strategy to achieve stability in the United Kingdom at 550 ppm at a carbon price under US\$50/tCO_2e, an increase of 2 per cent per year starting in 2007. HM Treasury indicated that a standard social discount rate of 3.5 per cent could be applied (Guo et al. 2006; Scarborough 2011).

There is another method to express the cost of carbon—which is by using marginal abatement cost (Hardisty 2009; Morris et al. 2008). MAC differs from market price for carbon which is determined directly or indirectly through public policy objectives. Based on the MAC, there is a cost of technological measures and processes to eliminate or reduce emissions (Enkvist et al. 2007). An actual carbon price signal might realise important mitigation potential in all sectors (IPCC 2007c). Although carbon pricing is difficult to control, it is worth considering how it could affect efforts to reduce emissions of GHGs. By imposing a cost on emissions, the carbon price inflates operational savings available from emission reduction activities. In particular, carbon price is considered one key way to capture opportunities for reducing emissions from sectors.

2.5.6 Verification

GHG emission trades to date have included Verified Emission Reductions (VERs) (Springer & Varilek 2004). In essence, this represents quantifiable change in emissions whose outcomes from a particular activity can be verified by a third party. One of the key drivers to trade in the early stages of this is to hedge such risks (Convery & Redmond 2007). Prices of these transactions hold some information about prices in the future because the trading of permits is likely to be valid in the first Kyoto commitment (Springer & Varilek 2004). However, there are serious doubts whether any particular reduction, regardless of how accurately quantified and monitored, will eventually earn a certificate in accordance with the rules of governments, which have not yet been developed (Heal 2007; Tietenberg & Nations 1998). Thus, buyers are expected to have the lowest willingness to pay for pre-compatibility permits. In contrast, the restrictions imposed on binding emissions create a natural source of demand from companies who meet the restrictions internally, and this would be expensive (Varilek & Marenzi 2001).

On the other hand, there is reason to wonder whether those price increases will be realised (Schmidheiny 1992). This drives the private sector to find innovative ways and cost-effectiveness to abate emissions (Hoffman 2005). Therefore, an effective MACC with actual and relevant data could help these firms and be the innovative driver.

Verifiable stakeholders could be located in seven main groups (Foster et al. 2001; Rankin et al. 2011): firm employees and management, shareholders and owners, customers, government agencies, Non-Governmental Organisations (NGOs) and the general public, verifiers and GHG emission reduction trading partners and intermediaries.

To verify various anticipations depends on what the company intends to accomplish with information of its own emissions (Bellassen & Leguet 2007). The company may, however, wish to use verification as a means to improve the inventory. If a company makes general obligations to reduce their emissions, then the company's verification has improved (Assadourian 2005; Foster et al. 2001). If a company intends to get some form of subsidy to reduce its emissions and is assured that it will not be punished in reducing emissions voluntarily, then verification expectations are greater. What a company wants to achieve by keeping track of GHGs emissions and, thus, the extent of activities achieved, depends on the position of its administration—which can change over time (Kolk 2009).

Current activities related to GHG emissions' verification fall into two main categories, verification of emissions' inventories at firm level and verification of emissions' reduction projects (Foster et al. 2001; Vine & Sathaye 2000). In addition, methods used in these activities are similar in many ways as they examine both accuracy and completeness of reported emissions (Vine & Sathaye 2000). Therefore, both usually include baseline emissions and emissions over a period of monitoring.

Company-wide emissions' inventories require verification of a historical baseline if the company is committed to tracking or reducing its emissions relative to their last year (Springer & Varilek 2004). The first year for estimating or measuring emissions could be used as the base year for the company. Any significant changes to the company's structure and actions would need to be modified, as well as any changes in methods used in calculating emissions. Any other changes affecting the image of GHGs would need to be included yearly (Foster et al. 2001). Changes may include a large company's acquisitions and divestitures, changes in product mix, outsourcing, and transfer of assets (Miozzo & Grimshaw 2011). If the company does not consider changes in its structure, it will use the base year emissions as the company's criterion for comparing between previous and current outcomes of any reduction in emissions.

Verification refers to collection of data to identify and prove environmental information according to specific objectives, for example, to verify emissions of GHGs, emissions over the past year (Trexler & Kosloff 1998). Verification requires development and implementation of a strategy (PCA 2002) which should incorporate:

1- Scope of the data being verified (for example, GHG emissions from a company's operations in all parts of the world);

2- Types of data collection (for example, measurement of GHG emissions data, the level of activities causing emissions, and emission factors to translate activity data in to emissions of GHGs); and

3- Performance of a battery of tests to make sure the information is correct (for example, to recalculate estimates of emissions).

Design and implementation of infrastructure at the level of the firm to gauge and report on GHG emissions is a relatively new and complex mission (Fiksel et al. 1999). This measurement must be integrated and undertaken in a firm's existing environmental management systems, leading to increased demand for human and financial resources (PCA 2002). Measurement of GHGs also provides a technical challenge (Arroyo & Peña 2003; DeSimone & Popoff 2000). Although there is a growing number of consultants, engineers and accountants who can assist firms to develop a strategy for GHGs, only a few firms have significant experience implementing these strategies (PCA 2002).

It is important for companies to manage environmental strategies before agreeing to emissions trading. The companies involved need to build credibility in their Partnership for Climate Action (PCA) (Pattberg & Stripple 2008). Third party verification of emissions as a prerequisite to trading formulates a procedural situation that could impede market activity (Lieberman et al. 2007). In addition, the use of third party auditors adds transaction costs for emissions trading, and there are currently no standards governing the adoption of auditors. The PCA (2002, p. 1) study conducted in the USA on a group of firms was compiled by Environmental Defense, whose "intent is to increase understanding of GHG issues through an exploration of the basic and interconnected building blocks of a credible GHG management program". This analysis is based on identifying common elements and the core practices of capacity building programs for nine firms in a PCA. Every firm of the PCA independently and voluntarily designs its management of GHGs. A review of each firm's program reveals its main elements, which can then be related and compared with a global framework designed program. These elements are setting goals, measuring emissions, taking action to reduce emissions, and accountability (PCA 2002; Price et al. 2008).

The PCA based its framework of evaluation on an organisation of the United States Acid Rain Program for sulphur dioxide emissions trading. The Acid Rain Program's design was used by the PCA to determine how to apply and control GHGs internationally and showed businesses how to start implementing their own programs for reduction in GHG emissions (PCA 2002).

Further discussion with businesses of the Acid Rain Program revealed additional information to benefit the emerging GHG programs by the PCA, both regulatory and voluntary. Firms in the PCA program who wanted to follow regulatory and/or voluntary practice used this information to design their individual frameworks. These frameworks represented the basic design decisions made by each firm in the design of their own approach to reduce emissions of GHGs. The details of each design highlighted the differences between each firm's estimation and calculation of emission reduction (PCA 2002; Skjærseth & Wettestad 2008).

Verification is significantly important for environmental data and may lead to actual worthwhile information (Ramanathan & Xu 2010). Quality control of emissions data commences with a solid basic foundation that is further supported by internal auditing, a process that is managed centrally by companies in the PCA. This process can be similar to a financial audit. It is a quality inspection during a second review by a third party verifier, and is increasingly being used by firms. Though all firms of PCA use or intend to use third-party verification, there are no uniform guidelines for conducting such reviews. In addition, the reviews are relatively new and there are few third-party auditors. However, those few who have conducted public and private reviews conclude that data management systems could develop greenhouse gas inventories. These inventories could then show more realistic estimates of the reduction in GHG emissions. This would confirm that the stock reflects accurate operations and covers the actual sources of material GHG emissions (Foster et al. 2001). These estimates and reductions would improve the firm's protocol and would have more consistency with the International Performance Measurement and Verification Protocol (IPMVP).

The International Performance Measurement and Verification Protocol (IPMVP) is an important tool in determining energy savings (Dietmair & Verl 2009). This method aims to increase certainty, reliability and level of savings (AEPCA 2004). It offers some options that determine savings (A, B, C, D). First is option (A), Retrofit Isolation (Key Parameter Measurement), which says that savings may be determined by field measurement of the key performance parameters. In fact, typical applications can contain a lighting retrofit, where the power drawn may be monitored and hours of operation are possible to be estimated. Option (B), Retrofit Isolation, says that all Parameter Measurement savings can be determined by field measurement of all key performance parameters that describe the energy use of the ECM-affected systems. Typical applications can contain a lighting retrofit where both power drawn and hours of operation are possible to be recorded. Another tool is option C (Whole Facility) which sees that savings may be determined by measuring energy use at the whole facility or sub-facility level. Typical examples can consist of measurement of a facility where several ECMs may be implemented. Lastly, option (D), Calibrated Simulation, means that savings can be determined through simulation of the energy use of the whole facility. Typical applications can include measurement of a facility where several ECMs might be implemented. However, historical energy data are not available. In line with the above discussion, it can be concluded that IPMVP is an appropriate tool for calculating and measuring energy saving (AEPCA 2004; Energy & Savings 2001). Therefore, this study will calculate actual energy saving and GHG emission reductions by using the IPMVP, which will strengthen mechanisms for measuring, reporting and verification of emissions. IPMVP concentrates on the general aspects of every firm in all sectors. However, companies in specific sectors will need to calculate GHG inventories that are peculiar to their sector (Lazarowicz 2009). Therefore, ways to reduce GHGs while maintaining a sustainable economy need to be identified and implemented.

2.6 Energy and emissions management

There are many pressures on companies to measure and manage their emissions of GHG—not only from regulators, but also from the market. Many clients and investors are interested in preventing harm to the environment by buying products and obtaining services that have minimal effects on GHGs and, moreover, may also be motivated to boycott firms that do not reduce emissions of GHGs on their own accord (Pachauri 2001).

There are a number of opportunities available to support the effective quantification and verification of GHG emissions. Organisations can take the necessary measures to achieve these opportunities to improve understanding of potential impacts of GHGs while providing a sound basis for GHGs management strategies in the future (Bryan Hannegan & Savitz 2011). Science and advanced technologies are needed to reliably measure GHG emissions, regardless of geography, sector or source (Reiner et al. 2007).

In 1992 the first environment management system standard called British Standard 7750 was created (Kirchenstein & Jump 2006). It was followed by an international environment management system standard (ISO14000). This standard has a series of international standards in environmental management. ISO 14000 has provided a framework for the development of the system and underpinning audit programs. Also, ISO has developed 14064, a standard for accounting for GHGs (ISO standard on accounting for greenhouse gas emissions). Organisations need to deem the advantage of utilising both standards as a means of achieving their goals of environmental management, and they need access to objective external audit evidence to achieve these goals (Jackson 1997; Omer 2008).

Understanding technology, science and methods are increasingly important in supporting climate change programs, improving public understanding of climate change and its potential impacts, and creating a solid base for mitigation measures in the future (Baker et al. 2009; Bryan Hannegan & Savitz 2011). On a larger scale, this requires a variety of measuring and monitoring methodologies that can be applied to a range of sources to be used in different geographical regions and economic sectors (Lemon et al. 2004). There will be a need for information technology infrastructure and support programs to provide acceptable accuracy of results at a reasonable cost (Wexelblat & Srinivasan 1999).

In climate change studies, another important issue is the influence of technological change on abatement costs, as indicated in the work of Gillingham et al. (2008), Clarke et al. (2008) and Weyant, J. P. (1993). Technological changes play an important role in mitigation of GHGs. These reflect energy efficiency efforts in sectors to help cut business costs, reduce dependency on energy imports and abate GHG emissions (Böhm & GmbH 2006). Figure 2.9 illustrates the program used by firms to manage instruments and human behaviour changes to achieve energy efficiency and emission reduction.

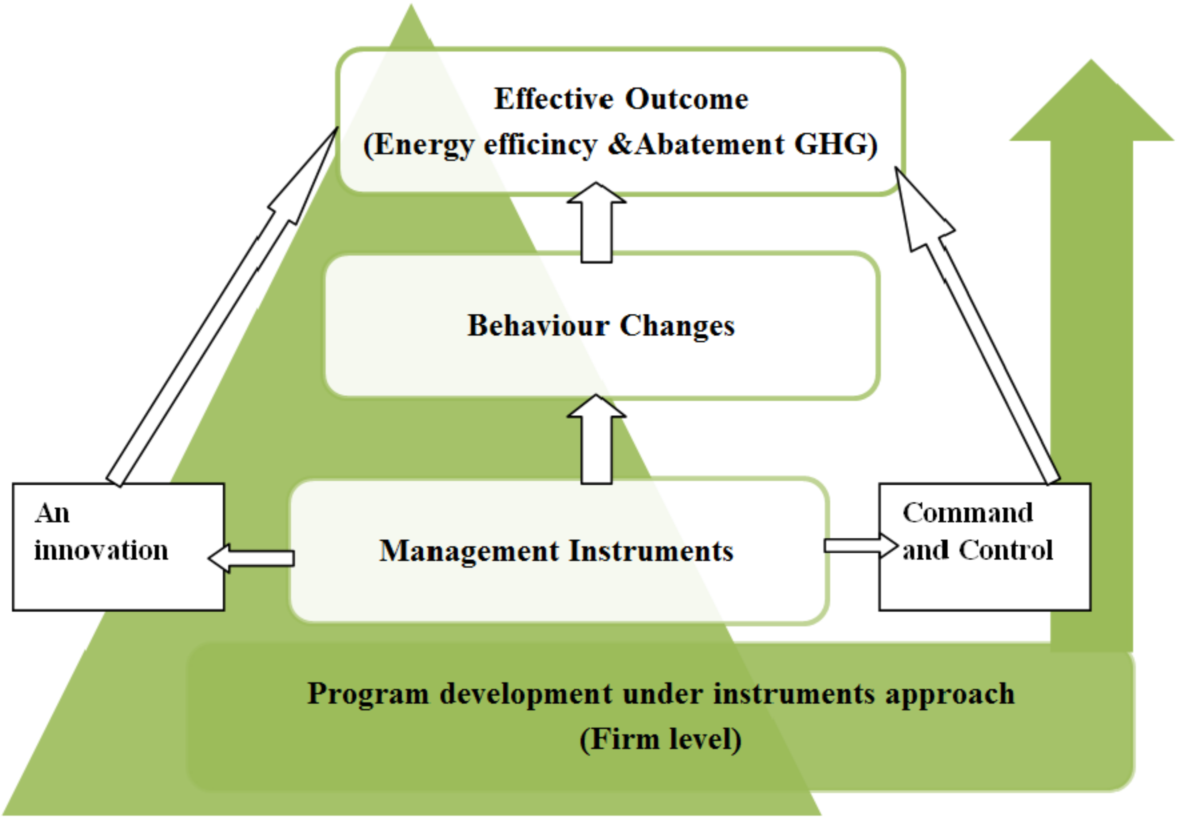

Figure 2.9 Program development under the instruments oriented approach
Source: adopted for this study

Instruments and tools play an important and significant function in reducing a firm's energy and emissions. One of these tools is the Command and Control (CAC) method which is a management method for controlling emissions.

2.6.1 Command and control

Environmental issues are of great interest to many governments as they look for solutions to environmental problems. A scientific system for management of energy is supported by a broadly-accepted methodology which may help governments formulate logical objectives for energy savings and emission reductions (Liu et al. 2011). CAC regulations may be one of these methods. CAC regulations can be defined as a way by which courses of action needed are determined and punishments associated with non-compliance are administered (Jaccard et al. 2002). It is essential to note that costs of different types of policies (CAC or market-based) may also vary (Lehmann 2011).

In the past, governments used CAC policies as a major strategy to control pollution (Lehmann 2012). CAC strategies can be appropriate complements to policies for pollution control (Jaffe et al. 2005; Lehmann 2011). A study in Japan found that a CAC method is likely to be able to provide regulated companies with motivation to increase new and creative technologies for controlling pollution (Hamamoto 2006). CAC approaches are likely to provide companies with flexibility in selecting pollution abatement technologies and motivate them to increase their efforts in developing cost-efficient methods to control their emissions (Hamamoto 2006). Enhancing the level of technology requires strengthening local R&D. Also, global technologies can help the process (Liu et al. 2011). On the other hand, organisations may not adopt this policy, regardless of its environmental benefits. The reason behind this is that managers might focus on profitability of their businesses rather than the environment (Liu et al. 2011). For some time, people have believed that market-based methods (taxes, tradable permits) are better than the CAC method (Lehmann 2012). Therefore, in order to gain more improvements, firms can use innovations or interventions to enhance their environmental conditions.

2.6.2 An innovation

It is broadly known that environmental innovations decrease marginal abatement costs. Porter (2004) hypothesises that it is possible to judge technological innovation by analysing R&D efforts and productivity changes within existing regulations of the environment (Hamamoto 2011; Lanoie et al. 2008). This hypothesis has been supported by many studies which have provided empirical support (Hamamoto 2006; Kammerer 2009; Lanoie et al. 2008). Palmer et al. (1995) state that environmental innovation may decrease the marginal abatement cost at all levels of pollution. Moreover, Jaffe et al. (2005) found that technological innovations normally reduce the marginal cost of pollution per unit. In Japan, Hamamoto (2006) identified significant relationships between innovation activity and both total factor productivity and environmental regulations. By measuring environmental innovation, Brunnermeier and Cohen (2003) statistically found an important relationship between pollution abatement costs and environmental innovation. On the other hand, some believe that environmental innovation may not necessarily reduce the marginal cost of pollution abatement (Bréchet & Jouvet 2006).

It is important to note that innovation can be categorised into four types. In relation to energy, the first type (Type I) of innovation is considered as an increase in the ratio of energy use over emissions. Another two types of innovation are Type II and Type III. They are broadly recognised (in industrial organisations) as process innovation/research and development. In the last form, Type IV, innovation may reduce any extra emissions beyond the limit imposed, with the objective of the firm reflecting abatement costs explicitly (Amir et al. 2008). It is observed that innovation may be seen from different sides. From the above discussion, it can be surmised that most previous innovation studies have focused on industrial companies. However, there is still much to be done in some areas to achieve the desired results required—such as changing consumer behaviour effectively towards sustainability (Csutora & Zsóka 2011).

2.7 Behavioural changes

Human behaviour is the way people behave in society, both socially and environmentally. Human behaviour can be understood by drawing on a number of scientific disciplines such as psychology, sociology, behavioural economics and neuroscience (Allen 2012). During recent years, behaviour change has gained attention in politics with the UK House of Lords, Science and Technology Select Committee's Commission of Enquiry on Changing of Behaviour and the establishment of the Cabinet Office Behavioural Insights team (Kaplowitz et al.

2012; Steg & Vlek 2009). Any analysis needs to weigh up costs and benefits. Estimating the cost-effectiveness of the full range of costs and benefits of different strategies needs to include effects of both social and business costs and benefits.

Various studies of environmental behaviour assume that individuals make logical choices and choose alternatives with higher benefits and lower costs (Bolderdijk et al. 2012; Steg & Vlek 2009). The Theory of Planned Behaviour (TPB) could successfully explain different types of environmental behaviour, including the choice of travel method (Kaiser & Gutscher 2006; Schade & Schlag 2003), household recycling (Taylor & Todd 1995), waste composting (Mannetti et al. 2004), purchasing power-saving light bulbs, use of paper, use of water, consumption of meat (Harland et al. 1999), and general behavioural that is pro-environment (Kaiser & Gutscher 2006).

Assessing the effectiveness of interventions is very important and needs systematic assessment of the effects of interventions (Almihoub et al. 2013b). Until now, most studies have focused on assessing informational strategies; modus operandi have been studied and effectiveness of structural strategies adopted (Abrahamse et al. 2005; Schultz et al. 1995). However, to the extent that organisational structures and incentives strongly influence community environmental behaviour, structural strategies may be more effective in promoting pro-environmental behaviour. In this respect, it should be noted that there are some important elements of behavioural changes that should be taken into considerations such as acceptance of behavioural change, knowledge and attitudes (Figure 2.10).

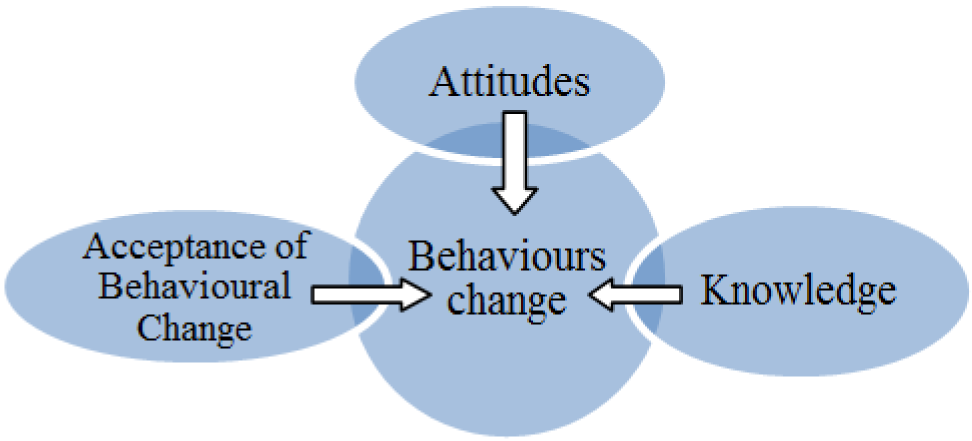

Figure 2.10 Elements used to understand behavioural change

Studies should be aimed at evaluating the effectiveness of intervention using experimental research designs that reveal the effectiveness of an intervention, as well as packages of interventions and research with more 'treatment' groups and a control group for comparison. Interventions may not only have short-term effects (Abrahamse et al. 2005), they may also have effects in the long-term. Most effects measure and only focus on changes in environmental behaviours. Firstly, it is important to monitor the changes in behavioural determinants because this increases understanding of what was a successful intervention program or not. Secondly, it is important to monitor the changes in environmental impact because this is the ultimate goal of behavioural interventions. Thirdly, one could ascertain changes in people's quality of life, which is a significant constituent of a broader concept of sustainable development. Until now, most studies have examined (Steg & Gifford 2005) and anticipated changes to quality of life, but rarely are any studies used for actual changes to environmental policy change and/or to create a human behaviour policy. There are differences in anticipated changes and the actual changes in the perceived quality of life. One hypothesis is that environmental policies could not significantly decrease the quality of life of people, at least not in the long term. Individuals adapt to changes in their lives positively or negatively by changing their standards, aims and anticipations (Diener 2000; Ormel et al. 1997). Thus, despite the fact that environmental policies may change perceptions of quality of life in the beginning, individuals can adapt or undo change.

Assessment studies using experimental designs are generally expensive and time-consuming (Steg et al. 2006) and this approach may not always be possible. However, these assessment studies did not reveal systematic evaluation but concentrated only on the extent to which the intervention succeeded in changing behaviour and reducing the environmental impact. They also failed to explain why it was unsuccessful, and how it can be adapted to increase the effectiveness of the intervention (Abrahamse et al. 2005). They informed the need for business to improve or replace the behaviour of a particular intervention—which enables such businesses to provide feedback to the targeted population and inform them of the effectiveness of efforts to improve the quality of the environment (Abrahamse et al. 2007). This may enhance the commitment to change their behaviour, and to keep the changes that have already been implemented.

Many researchers have studied environmental effectiveness as they perceive it and accept environmental policies before they are implemented, particularly in the field of travel (Loukopoulos et al. 2004; Schade & Schlag 2003; Steg & Schuitema 2007), but also in the use of energy (Steg & Gifford 2005). Most studies have examined individual factors related to the perceived effectiveness or acceptance provisions. These studies show, among other things, that strategies are more satisfactory when they are thought to be more just, and when they do not have a serious impact on individual freedoms. Furthermore, people who are very aware of the problem and feel a strong ethical responsibility to reduce the problem are more accepting of policies. A few studies have examined the effectiveness of perceived acceptance of features and specific policies such as rewards or sanctions, or the type of behaviour being targeted (Poortinga et al. 2003; Steg et al. 2006). Policies that increase the attractiveness of pro-environment behaviour are more effective and acceptable strategies in reducing environmentally harmful behaviour (Steg et al. 2006). Additionally, people desire policies to enhance the adoption of energy-efficient approaches rather than policies aimed at decreasing the use of current equipment (Poortinga et al. 2003; Steg et al. 2006).

It is sometimes possible to become pro-environment instead of cost-effective because of external barriers to environmental work (Stern 1999). Therefore, circumstances may need to change. Those behavioural choices are made so as to increase employment opportunities of individual pro-environment and thus to make behaviour choices of pro-environment relatively more attractive (Stern 1999; Thøgersen 2005)

2.7.1 Acceptance Behavioural Change

Energy use is widespread, and this leads to increases in energy demand. Although many efforts have been directed to more friendly environmental sources of energy, fossil fuels are still the major source of energy, resulting in negative environmental influences. There is a need to reduce the use of energy to the level of the company to achieve its goals of sustainable energy, as well as other policies. Reductions in energy consumption can be achieved by using energy more efficiently via investment in energy-efficient appliances, conservation energy measures and through the adoption of energy-efficient lifestyles—in short, by changing user behaviour.

Climate change and energy use issues trigger universal social transformation processes and technology which are based on new technologies such as energy savings, low-carbon cars and energy-saving building technologies (Ulli-Beer et al. 2010). In order to avoid costly change processes resulting from independent and radical results from market forces, key decision makers need to visualise and manage the path of ecology effectively. Consequently, sufficient transition management models are critical, particularly to the growth of understanding in the processes which affect the acceptance of new technologies.

A behavioural change is almost considered a social behaviour change. Social behaviour patterns and social balance are often used as guiding stable values such as social norms. However, behavioural change may change environmental conditions (such as climate warming, and scarcity of resources) and requires acceptance of new technologies. Antecedents of behavioural change are changes in overall value that can be reached in advance when they show new patterns of behaviour and social balance.

There are many studies that have shown that acceptance of options relating to energy savings could be more pronounced in groups of higher education (Gilg et al. 2005; Olsen 1983; Rohde et al. 2012). Results from Poortinga et al. (2003) suggest that acceptance of strategies to reduce energy use behaviour was less in people with lower levels of education. It is also important to note that people with higher education levels seem to be more willing to invest in energy-efficient appliances. However, research has shown that in most cases, an increase in knowledge and awareness has not led to pro-environment behaviour (Kollmuss & Agyeman 2002). Furthermore, nowadays, most of the environmental non-governmental organisations (NGOs) still base communications campaigns and strategies on the assumption that the simplification of more knowledge will lead to more enlightened behaviour (Doh & Guay 2006).

There is much evidence to suggest that earlier financial incentives can actually compete with feelings of civic responsibility. Frey et al. (1987) found that financial incentives may actually discourage the types of behaviours needed to solve social problems such as global climate change. Almost all environmental issues involve some idea of the public good. Behavioural experiments show that social good may undermine mere mention of money. In contrast to most of the policy recommendations, economists rely on cash incentives to address the problems of collective choice. This can have adverse effects. Several environmental scientists (Gowdy 2008; Norton 2005; O'neill 1993) have proven when giving individuals shared accountability that are directly attractive to the sense of the common good, this could be a more effective way of gaining acceptance to alleviate climate change and other environmental strategies.

Behavioural changes can be an important element in reducing emissions of GHGs and the fight against climate change. Basic criteria used in some research reports and case studies are that behaviour change: a) must be the result of the individual workers being a part of the decision making process; and, b) the results have a clear link and are directly related with low GHGs emissions (for example, low power consumption). Thus, any actions those individual workers make to changes in previous work practices leads to a reduction in GHG emissions. This relates to behaviour change (Ezra M. Markowitz & Doppelt 2009).

Fossil fuels are the main source of energy in the United States, Australia and most other industrialised nations nowadays, which means GHG emissions are common (Ezra M. Markowitz & Doppelt 2009; Gardner et al. 2009). Since the first round of oil crises in the 1970s, academic researchers, utility companies, business managers and others have spent a great deal of time and energy studying ways to reduce the use of fossil fuels. Most of the studies concentrated on improving energy efficiency in buildings (Abrahamse et al. 2005; Stern 1992) and there have been some successes in this regard. The vast majority of research described in this section did not directly measure changes in GHG emissions pertaining to behaviour change (with a few notable exceptions); the research recorded all changes in energy consumption, which is assumed to be a surrogate for the reduction of GHGs. Because the vast majority of previous research has focused on reducing energy by families and organisations, it is important to examine these areas (Bauen 2006). Reducing GHGs emissions through reductions in household energy and regulatory conditions include a wide range of related interventions that stimulate behavioural changes.

An important first step in motivating people to change their behaviour deliberately is to capture their time and attention. However, what happens after someone gives their time and attention to the issue is the focus of many research topics. To persuade people to focus on and participate in a program to reduce energy requires significant behavioural changes; therefore, interventions require methods that attract attention. The methods adopted were at least five primary approaches to attract attention and secure commitment of time: 1) door-to-door 'to seek'(Winett et al. 1985); 2) mailed information about the project or campaign (Schultz et al. 2007); 3) talking to people on the phone (for example, Baker, 1978; Department of Environment and Heritage, 2005); 4) placing ads (Hayes & Cone, 1981); and 5) taking advantage of social communication (Stern 2002). As a result, obtaining commitments of time and attention are important because many of the interventions that have been developed to reduce emissions of GHGs by changing behaviour require a high level of preparation. Conscious knowledge of new information by individuals relies on subconscious simple operations, such as stimuli and response mechanisms. These operations require some cognition 'open' to the researcher or practitioner to work with. This 'open' awareness is critical in gaining important benefits from the interventions.

The negative impact-oriented research and complex environmental research demonstrates multiple behavioural motivation to use energy (Guagnano et al. 1995; Lorenzoni et al. 2007). Also, a range of internal and external barriers limit the pro-environmental value of the work relationship (Kollmuss & Agyeman 2002). Thus, effects on the environment reflects the importance of behaviour such as energy use, which Stern (2000) sums as attitudes, values and beliefs relating to the environment, but also to other considerations including comfort, aesthetics, quality, time spent with family, and so on. A second important step is contextual forces. They include sources such as social, economic, institutional and political factors, then personal capabilities (e.g., knowledge and skills). Finally, the above behaviour is intended to evolve into subliminal habits that will lessen environmental influence.

2.7.2 Knowledge

Although studies have found that knowledge is not the only element of the decision to enter into pro-environmental behaviour, knowledge does play an important role (Marcell et al. 2004). It is possible a general misunderstanding may lead to a complex issue in environmental problems and create significant barriers to behaviour change and education (Oleckno 1995). There is knowledge that a user's behaviour has a significant impact on energy use. Also, saving potentials, possibly from a technological point of view, are dependent on user behaviour. A large number of studies on technical possibilities allow new technologies to create more potential energy savings. It is clear that energy consumption also depends on attitudes, preferences and income, as well as relative prices (Kriström 2008). The difference between varying energy usage and behaviours of energy users is relatively unknown.

Kaiser et al. (1999) state that factual knowledge could be seen as realistic for any attitude and, therefore, the relationship between factual knowledge and behaviour can be mediated intention as well. Furthermore, personal norms also broker the standards and values of individuals according to intent and thus predict behaviour indirectly. Because of these interrelationships and the outcomes of research in the environmental field, each fit with each other well. Therefore, an increase in awareness or knowledge may lead to change in energy use behaviours which, in turn, can lead to a decrease in consumption (Hargreaves et al. 2010).

Hines et al. (1986) research titled "Model of Responsible Environmental Behaviour", which is based on a theory of planned behaviour created by Ajzen and Fishbein (1980), is a meta-analysis of many previous studies' pro-environmental behaviour research (Ajzen & Fishbein 1980; Hines et al. 1986; Kollmuss & Agyeman 2002; Sia & H.R. & Tomera 1986). They found that there are variables associated with responsible pro-environmental behaviour including, firstly, knowledge of issues, which means the person must be familiar with environmental problems and its causes. Secondly, knowledge of business strategies: the person knows how to or has to work to reduce his or her impact on the environmental. The locus of control will stem from the individual's perception of his/her ability to bring about change through his/her own behaviour. People who suffer from powerful pro-environmental attitudes are more likely to engage in pro-environmental behaviour; however, the relationship between attitudes and actions proved to be weak. Thirdly, verbal commitment—which is the willingness to take action to inform and which also provides some pointers to a person's willingness to engage in pro-environment behaviour. Finally, people who have a greater sense of personal responsibility are more likely to be engaged in environmentally responsible behaviour.

2.7.3 Attitudes

Knowing the attitudes of people toward the use of technology is important since an individual's emotional reaction can affect the use of the technology implemented (Venkatesh et al. 2003). Though attitudes are not solely responsible for prediction of pro-environmental behaviours, attitudes have an influence on the selection of sustainable behaviour. It is not easy to encourage change in environmental behaviour if people do not see that their behaviour makes a difference (Rydin & Pennington 2000). It is also difficult to see, hear, touch or smell the effects of climate change on a regular basis or ascertain that daily volatility in weather directly impacts climate change; it is difficult to see how one change in behaviour makes a difference in GHG emissions (Marcell et al. 2004). This may indicate that the social marketing programs are more effective in changing behaviour in electricity use, transfer of knowledge on climate change, and improving attitudes toward taking action to avoid or reduce GHGs (Marcell et al. 2004).

The change-oriented approach opens up the black box of behaviour, and is aimed at changing the behaviour that occurs if people are motivated and enabled to change. This approach has focused on the factors that motivate people to change their behaviour (Venkatesh & Morris 2000). These are ‘stimulus’ factors and include awareness, knowledge, attitude, social and personal norms, and self-efficacy (Bo Dahlbom et al. 2009). These factors could lead to an intention to implement a desired behaviour. These are internal and intrapersonal factors.

An alternative theoretical approach that might be called, in the broadest sense, ‘attitude approach’ analyses, is another way for thought or cognitive behaviour precedents to guide behaviour. From this theoretical perspective, different models have been proposed, for instance, value ‘attitude’ behaviour model (Guagnano et al. 1995; Hsieh et al. 2008; Taylor & Todd 1995), the theory of reasoned action and its successor, the theory of planned behaviour. On the other hand, many studies are not based on the theoretical models mentioned above; therefore, it could consider the role of socio-economics and variables of demographics (Berger 1997), and the role of public environmental attitudes such as environmental concerns and environmentally-responsible consumption (Mannetti et al. 2004).

There are various models that have been proposed, including the technology acceptance model (TAM) (Davis 1989; Davis et al. 1989). These models are adapted from Theory of Reasoned Action (Ajzen & Fishbein 1980; Yang & Yoo 2004) and provide a powerful explanation to change user behaviour. TAM is intended to impact user acceptance determined by two core beliefs, namely, perceived usefulness and perceived ease of use. Perceived usefulness is known as the extent (degree) to which a person believes that the person using a special technique will enhance her/his functioning, while perceived ease of use is defined as the degree to which a person believes that the use of technology will be free of effort (Davis 1989). Therefore, durability of TAM has been established through many applications and replications (Davis 1989; Taylor & Todd 1995; Yang & Yoo 2004).

All decisions of initial and continuing acceptance are important and deserve attention. Incompatible results have been reported from previous research. For example, it has been suggested that Taylor and Todd (1995) individually tended to underestimate the importance of perceived control considerations when forming behavioural decisions to accept intention. Hu et al. (2003) note that perceived ease of use can be seen to be overly stressed when an individual has limited knowledge or experience of technology. From a research perspective, there is a need to continue the investigation to re-examine and reconcile these inconsistent results and thus enhance the theoretical and experimental mainstay applied (Hu et al. 2003; Legris et al. 2003). Results can also benefit organisational technology management practices, for example, to enable the design of effective management interventions for sustainable user acceptance.

Interestingly, the theory of TAM in the reference theory of reasoned action includes social impact through the construction of so-called ‘subjective’ norms. Previous research by Ajzen (1991) found that in the psychology subjective norm there can be important factors and/or intention behaviour. However, TAM excludes this because of the problems of building theory and measurement (Davis et al. 1989; Venkatesh & Morris 2000). Subjective norms are expected to be perceived from personal key references to performance behaviour of interest (Ajzen 1991; Hsieh et al. 2008). Through subjective norm, it is reasonable to expect that determining technology acceptance can be based on the theory of reasoned action and the theory of planned behaviour. Moreover, there is empirical evidence to support the role of building theory being somewhat mixed (Ajzen 1985, 1991). However, most companies can minimise GHG emissions by managing efficiency barriers more appropriately (Farhat & Ugursal 2010).

2.8 Behavioural implications and barriers to using MACC

One of the most effective means of reducing the growing threat of global warming caused by human use of fossil fuels is to reduce energy use (IPCC 2007b; Solomon 2007). According to the prevailing economic theory, barriers related to reducing energy use include market failures (Golove & Eto 1996). In terms of the cost of maintaining or reducing energy, studies on the implementation of effective measures are not generally implemented because of the existence of barriers to energy efficiency, resulting in a gap that is called energy efficiency gap (Thollander & Ottosson 2008). A barrier could be defined as a mechanism that is designed to prevent investment in technologies that are both energy-efficient and economically efficient (Csutora & Zsóka 2011). Therefore, the barriers related to efficiency are economic/financial barriers, behavioural barriers and organisational barriers (Gillingham et al. 2009; Koeppel et al. 2007; Sorrell 2004).

In addition to the price of carbon, economic barriers and non-price barriers also need to be addressed to secure the greatest opportunities to reduce emissions that have been identified as realistically achievable by 2020. These barriers include market structure and supply (LCGPA 2010). In terms of economic barriers, these involve hidden costs and overhead costs such as the cost of collecting and analysing information and disruption of production (Jaffe & Stavins 1994). Access to capital may result in barriers; for example, a small budget can affect investment in energy-saving technology (Rohdin & Thollander 2006). Moreover, why are organisation energy-efficiency measures constrained by short pay-back criteria? This question can be explained by risk aversion (Sorrell et al. 2000). Organisations with corporate sustainability management systems are also demanding that their suppliers meet similar standards. Similarly, suppliers can also affect a corporation’s performance. This forces businesses to develop in order to have a competitive edge (Porter 2008).

Limited demand from customers in many sectors and firms, as well as an overemphasis on how significant the customer thinks the environment is (because of the dissonance between attitude and actual consumer behaviour), has led to emphasis being placed on customer demands with regard to sustainability commitment by an organisation (Haas et al. 1998; Haas & Biermayr 2000).

Homogeneity of cost-effective energy efficiency measures are not always able to be implemented because the technology is not adopted by the company (Thollander & Ottosson 2008). A large body of research has documented that consumers have often obtained incomplete information about market conditions, characteristics of the technology and the implications of company behaviour (Gallaher et al. 2005; Howarth & Andersson 1993). Major industrial relationships worldwide understand that they cannot have strict control and monitoring by principles; consequently, this can result in neglect of energy efficiency measures (Jaffe & Stavins 1994). Negative buyers may select goods on the basis of visual aspects such as price. Good buyers are more knowledgeable about the energy performance of the product (Thollander & Ottosson 2008). Split incentives and their implementation may become less useful if the person or department cannot obtain the benefits from investment in energy efficiency (Jaffe & Stavins 1994). Therefore, to reduce economic barriers for emissions abatement, behaviour is another barrier that needs be taken into consideration.

In terms of bounded-behaviour, theoretical decisions are based on incomplete information rather than an authentic basic rule (Simon 1957). Resistance to change within organisations could lead to the neglect of energy efficiency measures (Sorrell 2004). Credible information from sources that are trustworthy can provide successful energy efficiency measures (Unruh 2000). The form of this information should be specific and simple to increase acceptability (Thollander & Ottosson 2008; Worrell et al. 2004). There are people in organisations with real ambition to improve energy efficiency who would prefer to be represented by an individual within key senior management so that people in organisations can be heard and acceptable proposals disseminated (Stern 1992). To reduce organisational barriers, an organisation's culture can include, for example, a group of individuals carrying environmental values that encourage investments in energy efficiency (Blok 2004). In managing real barriers, both behavioural and organisational obstacles need to be considered. The lack of authority within departments of energy could lead to a low priority regarding barrier issues within organisations (SPRU 2000). Therefore, management of climate change leads to more concentrations of specific barriers on approaches and methods such as a MACC approach.

MACCs can use various methods widely with differing underlying assumptions, and discount rates assumed. Therefore, a number of possibilities for reducing emissions and costs can be estimated (Akimoto et al. 2012; Erickson 2010). The key factors that contribute to differences between MACCs' methods include projections of baseline emissions (which include mitigation measures in the base), the availability and cost of abatement options, the time it takes for implementation of mitigation, whether the model considers demand side responses to behavioural changes, and structural adjustments in the economy such as changing the prices of energy (Amman et al. 2009; Van Vuuren et al. 2009). In the energy sector, MACC research has found that models which include behavioural change can display twice as much (a carbon price) as the mitigation potential of models that did not include behavioural change (Amman et al. 2009).

Use of MACC methods evaluates the possibility of reducing vulnerability of many restrictions (Munasinghe et al. 1996). Top-down models tend to lack specific technical details of a sector. These models need to assess where opportunities exist and how to mitigate potential compensation mechanisms and other funding sources that have emission reduction credits (Hoogwijk et al. 2008). However, they can succeed at reflecting economic relations between regions and between products and sectors, as well as indirect effects of activities such as compensation leak emissions between countries or sectors (Blok 2004). Bottom-up models tend to be more useful to analyse the compensation offer because they can easily distinguish between technologies and sectors in a manner consistent with the best of the mechanisms and methodologies regarding how to compensate maturity, how to apply a separate project, technology, and/or sector-specific actions, rather than transform the economy on a large scale (Erickson 2010). However, the bottom-up approaches of MACCs are weak in terms of the acquisition of economic relations and indirect effects (e.g. leak); also MACCs can reduce transaction costs and unsubstantiated causes for reduction, which can offer possible compensation (Fisher et al. 2007).

Most MACC methods are subject to adoption of a path and a state of uncertainty. A MACC for any given year is assumed (either explicitly or implicitly) in world politics and technology that have taken a course from now until that year (Erickson 2010). Procedures and policy options in the early years greatly affect the prospects of reduction potential and costs in later years (Lazarowicz 2009). One means of solving this path dependence (as well as the uncertainty related to the underlying assumption) is to use a range of possible scenarios in the early years of the policy to generate MACCs for the analysis of alternative scenarios (EPA 2010b; Lazarowicz 2009). The above barriers lead to identifying difficulties that should be studied, particularly at a firm level.

2.9 Theoretical MACC vs. actual MACC energy consumption

Majcen et al. (2013), Branco et al. (2004), Haas and Biermayr (2000) and Marchio and Rabl (1991) studied the reduction of energy consumption. The study conducted by Majcen et al. (2013) appears to show that the consumption at theoretical level (which is calculated using different designs, policies and tools determined by a government's politics) often fails to accurately measure the actual energy consumption. An empirical study conducted in Norway by Pettersen (1994) established that total heating energy consumption cannot be accurately predicted more than approximately 35-40%, which corresponds to the case study of residential buildings conducted by Majcen et al. (2013) and others already mentioned. Reasons for these discrepancies are complex. One of them is the difference in the patterns of presence and comfort. With many of the calculation methods, especially those that are used for certification, this difference is deliberate.

There are many assumptions when using calculations in a MACC at the theoretical level that may lead to inaccurate estimations of theoretical abatement of emissions. It cannot accurately estimate energy expenditure; it also hinders the process of assessing potential savings; and seems to be a problem in all parts of the European Union states. Rogan and Gallachoir (2011), Geller et al. (2005) and Majcen et al.

(2013) examined the discrepancies between actual and theoretical energy consumption with respect to the specific national goals for energy saving and CO_2 reductions in the residential sector in the Netherlands. The study proved that most of the policy goals for energy and CO_2 emissions can be achieved through theoretical extrapolation of consumption per share a dwelling. However, when using actual consumption, almost none of the reduction targets over the next 20 years are achievable. Therefore, using actual data may lead to more credible results.

The theoretical calculation method only takes into account the energy for specific end uses and overlooks those uses determined by the occupants' lifestyle. It does not derive actual energy use or electricity consumption of the actual energy bills for firms in question; however, the theoretical calculation method does reflect the consumption for all possible purposes (Majcen et al. 2012). One important variable in the consumption of electricity and appliances, which is not taken into account in the calculation of the theoretical, is reflected in electricity bills (and therefore in databases).

At the theoretical level, Sanstad and Howarth (1994) noted the view that private enterprises using actual energy consumption produced optimum results as a rule; however, theoretical energy consumption produced imperfect results relative to welfare economics. They concluded that energy efficiency critics, who claim that there are no good market imperfections and that they are an expression of liberal political ideology, are defying empirical accuracy. Other perspectives such as economic costs, the cost of transactions, behavioural, the recognition of barriers such as bounded rationality, and the missing information and restrictions on market transactions can be considered (Geller et al. 2005; Sorrell 2004). This study aims to gain a better understanding of the significant differences between energy consumption by considering the impact of the interventions on energy consumption and emissions rates, theoretically and actually. Therefore this study aims to reduce the gap between the theoretical and actual MACC in an attempt to take advantage of the two approaches with respect to the provision of energy use and reduce emissions.

2.10 Research gaps

Many previous studies on MACCs have focused mostly on analysing their effects on a whole country basis or by sectors within countries (Cagatay & Mihci 2006; Chapman & Kaelbling 1991). Regions have applied MACC analysis across most sectors, but at a theoretical level (Baker et al. 2008). Although many studies have focused on one sector, undertaking a case study of individual organisations in one region across critical sectors appears not to have been undertaken. This approach is likely to contribute in time to the growing literature in this area to help regions and firms develop a plan for low GHG. This could add considerable net cost savings from more efficient energy use. Energy data collected will provide a before and after intervention analysis, as well as future scenario analysis based on different MACC methodologies and assumptions. It would appear that no other studies have been published that have developed MACCs at a micro (firm) level across sectors all in one region using actual measurements of costs and savings from interventions. Much of the projected outcomes from MACC studies have relied on theoretical measures, assumptions and methodologies. Little research has been carried out to test these theories. Using a longitudinal study to test and validate measures and MACC methodologies could make contributions to the extant literature.

Past research in the environmental sustainability field proposed that the gaps in this field's knowledge were the primary barriers to sustainable behaviour and decision-making. The study showed the impact of psychological factors of humans such as social norms, altruism, and perceptions of personal beliefs and attitudes in their decision-making behaviour (Ajzen & Fishbein 1980; Kollmuss & Agyeman 2002; Rydin & Pennington 2000). In relation to pro–environmental behaviour, social science has had difficulty in establishing a concrete relationship between the psychological characteristics of individuals' behaviours and the psychological characteristics of people's behaviours. Some theorists of social science have concluded that great significant complex, internal (individual, psychological, and social) and external barriers (institutional, economic, social, and cultural) restrict many people from making choices of behaviour which could bring more attention to climate change (Kollmuss & Agyeman 2002).

If future research focuses more attention on new behaviour techniques so that specific human behaviours (mentioned above) improve, what will be the consequences of GHG emissions from those specific changes? Practitioners and project developers need to know which behaviours could be changed and what it can reasonably expect to obtain from such changes (Ezra M. Markowitz & Doppelt 2009). While it can be difficult to obtain measurements or a reasonable estimate of abatement in GHG emissions as a function of different specific behavioural changes, it is important to have this information. Working in multi-disciplinary teams (Abrahamse et al. 2007) is a positive strategy to combat the tendency of researchers to leave it to someone else to translate the reductions observed in the use of resources such as energy and water. By combining experts' (such as psychologists, environmentalists and economists) concepts on behaviour change and well-versed individuals in the measurements of interactive related intervention outcomes, future energy and GHG projects may be able to provide a greater level of detail. This would need to include specific measurements for techniques of intervention so that behaviour change will improve the results for the reduction of GHG emissions. Thus, this study will attempt to fill these gaps.

2.11 Chapter summary

This chapter synthesizes the previous literature relevant to the research problem. It reviews the use of energy and its relationship to reduce emissions of GHGs at companies' level. Particular focus is given to energy, greenhouse gas emissions, accounting tools and methods, MACCs methods, the sectoral analysis, and management of energy emissions and behavioural changes are also reviewed. In addition, the theoretical and actual MACCs implications are discussed. This literature review identifies and discusses key issues in the field of research and its relevance to this study. The research design is provided in Chapter 3, which also develops the propositions and outlines the theoretical framework.

CHAPTER 3 : RESEARCH DESIGN

3.1 Introduction

A review of the relevant literature in the previous chapter shows the research on energy use and its association with a reduction in GHG emissions. The review further focuses on energy use and the importance of attacking increasing GHGs. Accounting tools and methods, including MACC, could be employed to help identify and measure emission and environmental costs reductions and their impacts. The literature for energy and emissions management identified important research problems which assisted in identifying the research gaps. This chapter details the research design, which includes the research questions, theoretical framework and propositions, in order to fill those gaps.

3.2 Study design

The study employs a mixed method approach to data gathering (Johnson & Onwuegbuzie 2004). There are two diverse philosophical traditions that support the view of positivism and interpretivism in social research and thus the predominant use of research methodologies—quantitative and qualitative (Lofland & Lofland 2006). Development at the theoretical level from a philosophical theme and the selection by the researcher to one methodology over another, in practice, is best appreciated when it is recognised that there is a different proposal for each method's results about social reality (Glaser & Strauss 1967; Weber et al. 2011). The results from each method will be juxtaposed with other investigations throughout the world: how researchers establish the truth of their demands, how they establish their various proposals about the social world, and how they view the truth from their data collection (Glaser, B.G. 1992; Kelle 2005). When different methods of approach are chosen, it allows the researcher to take advantage of the strengths of both qualitative and quantitative methods and potentially reduce the weaknesses of the respective methods (Onwuegbuzie & Teddlie 2003).

Yin (1994) has stated that the research design is the blueprint of the research. The design deals with four problems: what are the questions for study; what is the relevant data? What data will be collected and how to analyse the data to obtain results. "This is much more of a plan of action because the main objective helps avoid the situation that evidence does not address the initial issues of the research" (Creswell et al. 2007, p. 236). Moreover, the design of research deals with logical problems, and also determines how the investigator will address the critical issues of generalization and legitimization (Yin 2003). Therefore, propositions are derived to assist in answering study questions formulated from gaps that are identified from the literature.

3.3 Research questions

This study poses two main research questions to be answered by five sub-questions in attempting to fill the gaps identified. Companies seek to create more accurate cost information on environmental impacts and assessment of people's behavioural changes related to energy use. However, it is difficult for corporations to enhance management decision-making to reduce their energy use and GHG emissions without using more accurate methods such as a MACC. Therefore, there are two main research questions. The first main research question (**RQ1)** of this study is: **Can MACCs provide an accurate and simple interpretation of relative and total abatement costs for energy abatement?**

MACC studies have previously focused on effects to whole countries and to sectors within countries (Cagatay & Mihci 2006; Chapman & Kaelbling 1991). Regionally, MACC has been applied to analyse at a theoretical level (Baker et al. 2008). The purpose of this research is to identify the differences between estimated (theoretical) and actual MACC models at an organisation level, and in so doing develop a MACC methodology for this purpose. The MACC could use actual measurements of costs and savings from interventions so that, combined with theoretical MACC, it can obtain an effective method to provide cost information for enhancing internal management decision-making. This study attempts to identify an appropriate method—MACC—that can identify environmental costs and emissions reduction. This MACC method needs to provide alternative costs for decision-making in organisations and sectors In addition, the MACC can estimate and identify GHG emissions reduction and their expenditures separately in organisations and sectors (Smith 1992) Alongside traditional costs, MACC can pick up methods for environmental assumptions and provide cost information to enhance internal management decision-making (Bebbington et al. 2007; Scavone 2006). Environmental accounting, by using actual data, could decrease uncertainty when synchronised with theoretical MACC. Therefore, these determinations can capture actual data required by different stakeholders. In order to reach a set of actual data which is more accurate the following sub- research questions need to be addressed:

SQ1: *Are there any differences between estimate (theoretical) and actual MACC models at an organisation level?*
SQ2*: Are there any shortcomings in the MACC methodology?*

Investing in energy-efficient tools does not always improve energy saving as desired. There are difficulties measuring aspects of behavioural changes relative to reducing GHG emissions, but it is important to have this information. Managing people's behavioural changes relating to energy usage is a difficult and sensitive issue (Abrahamse et al. 2007). For the purpose of this study, specific measurements for techniques of intervention need to be included so that behaviour change will improve the results for the reduction of GHG emissions. These inclusions are user knowledge, users' attitudes and user acceptance of energy abatement initiatives.

Evaluating the effectiveness of interventions is significant and needs a systematic assessment of the influences from interventions. It should be noted that there are some important constructs of behavioural change that must be taken into account such as acceptance of behavioural change, knowledge and attitudes. Therefore, these are elements that are important in assessing behavioural changes. Steg and Gifford (2005) suggested monitoring changes in behavioural determinants because it increases the understanding of what intervention program is successful. They also proposed monitoring changes of environmental impacts, because this is the ultimate goal of behavioural interventions; one can get to know about changes in the quality of people's lives, which is one of the major elements of a broader concept of sustainable development. Therefore, the second main research question **(RQ2)** of this study is**:**

RQ2: Does user behaviour resulting from abatement activities impact on MACC methodologies?

This question is addressed by answering the following sub-questions.

SQ3*: Does users' energy management knowledge affect their behaviour to change their energy usage?*

SQ4*: What impacts do users' attitudes have on energy saving initiatives?*

SQ5*: To what extent does user acceptance of energy abatement initiatives have an impact on MACC methodology applied?*

3.4 Analytical framework

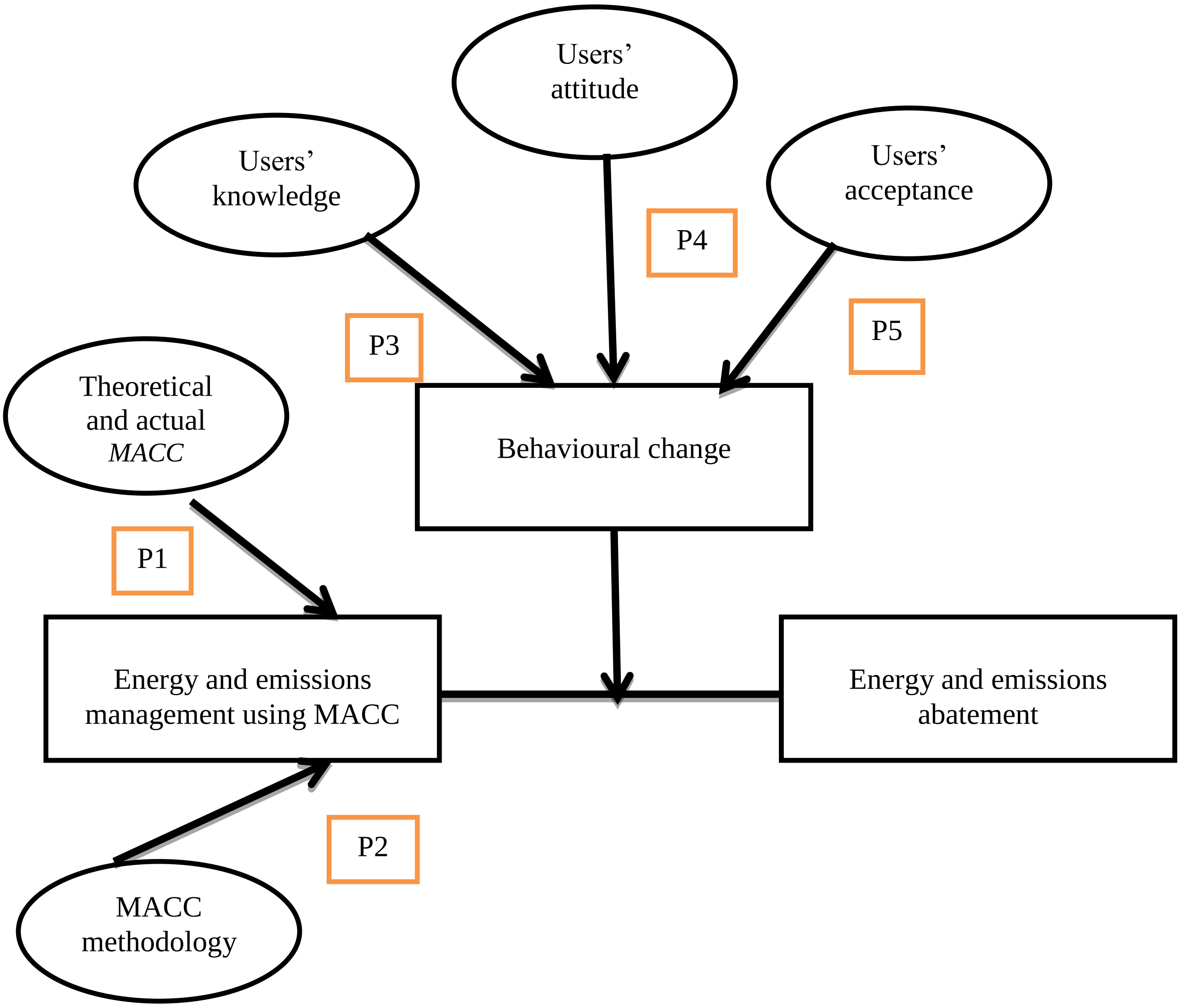

Figure 3.1: Framework for study

The conceptual framework of this study has theoretical underpinnings in two main constructs: energy management using MACC and human behavioural change. Behaviour change is measured by three dimensions: users' knowledge, users' attitude and users' acceptance. The theoretical framework purports that user behavioural change moderates the relationship between energy and emissions management using MACC and energy and emissions abatement. If users knowledge of energy saving (and emission reduction) technologies is average to high, behavioural change will positively influence the use of MACCs to reduce energy use and, consequently, emissions. Similarly, positive attitudes and acceptance of interventions will have a positive effect on energy and emissions reduction. These lead to the relationship between users' behaviour and energy and emissions management using MACCs; and also between users' behaviour and energy and emissions abatement. Energy and emissions management using MACC and energy and emissions abatement also using MACC, which was adopted for this study, is theoretical versus actual MACC. MACC methodology has developed, as illustrated in Figure 3.1. To identify organisation actual data, this study used actual interventions from real projects. The research used historical information to implement theoretical MACC. It established the difference between an organisation estimated MACC and an organisation actual MACC. Furthermore, MACC methodology has been recognised by leading organisations that their persistence with effective environmental management accounting can determine the best ways to reduce energy and emissions to improve theoretical and actual conceptions, as illustrated in Figure 3.1. To validate the theoretical framework, five research propositions are developed to answer the research sub-questions.

3.5 Propositions

Proposition one **(P1)** was framed to investigate differences in outcome between estimate and actual MACC models in being able to provide more accurate data to enhance cost management decisions and support reporting initiatives. A proposition is an unproven statement about a phenomenon that is examined by researchers through study (Koutsoyiannis 2003; Malhotra 2010). Firms can employ advanced MACCs to capture costs of environmental protection and disclose these benefits through their activities. The MACC methodology could help firms to strengthen internal management decision-making related to the management of these costs, as well as reduce emissions (Clo 2011; Jayasinghe-Mudalige et al. 2011). On the other hand, there are those who say that cost accounting data must be more accurate (Wang & Lin 2007). By using actual information, these techniques—MACCs—can assist businesses with how to reduce emissions in a more accurate and acceptable way for all stakeholders.

Typically, a trade-off between economic and environmental performance is provided by the MACC. A MACC links company-wide emissions to the cost of additional units to reduce emissions (McKitrick 1999). From the view of conventional theory, a MAC curve relies on two presumptions, efficiency of actual production; and separation between production and pollution abatement. These presumptions mean that emissions can be controlled by either pollution control or reducing output (Van Meensel et al. 2008). Outputs of a firm consist of fixed proportions of emissions (Whitcomb 1972). This strong link between output and pollution makes the exclusion of negative externalities difficult (Van Meensel et al. 2008; Whitcomb 1972). In other words, focusing only on decreasing negative externalities is always expensive (Van Meensel et al. 2008). Weak disposability only allows for a relative reduction of output and pollution (Shephard et al. 1970). Low negative externalities are more expensive. Conventional theory therefore always assumes a negative trade-off between economic and environmental performance. Thus, enhanced economic performance carries the worst environmental performance, and vice versa (Al-Tuwaijri et al. 2004).

Building a MACC on traditional theory has been criticised by several authors such as Rennings (2000), Hill et al. (1999), Wossink et al. (2001), and Wossink and Denaux (2002). Wossink and Denaux (2002) argue that production and reduction of pollution must be treated separately. This leads to appropriate account being taken of control choices provided by modifications in production practices. Negative externalities are often caused by specific inputs that have negative characteristics. Therefore, any amount of production at one time, whether intended or unintended, causes these negative external influences. Structures that are created for the marketing of these outputs and negative side effects depend on the chosen mode of production (i.e. not fixed). They are often dependent on causes of negative externalities. Options can be put in place such as replacing the input, replacing resources and introducing new production processes without reducing the level of production planned.

Wossink and Denaux (2002) found that improving efficiency can compensate for part of the costs associated with the best quality ecological production. Van Meensel et al. (2008) state that the more efficient use of inputs can lead to the attainment of both economic and environmental goals simultaneously. This means that improvements to the environment do not have to come at a cost (Wossink & Denaux 2002). If economic performance and environmental improvement succeed at the same time, a positive trade-off is established.

Companies would need environmentally sound production practices and evidence of how they reduce cost impact. Hill et al. (1999) distinguish between three main stages in the transition process using firm levels of environmentally sound production practices. Such levels include: (1) improving efficiency; (2) replacing inputs or production processes; and (3) re-design. That is, firms should reduce production or use new or additional technology for environmental purposes. Similarly, Rennings (2000) distinguishes between integrated and additional measures. Integrated measures address directly the issue of emissions during the production process, while the added measures are ‘end of pipe-oriented’ and occur after actual production (West 2012).

Additional measures are aimed at reducing pollution after having already produced. These measures are always expensive, therefore implying negative economic and ecological trade-offs. Integrated measures address inputs and outputs, transformation of the relationship with external factors, and increasing profits. These measures include improving efficiency, adapting to size, rearranging inputs and the introduction of environment-friendly inputs, using cheaper inputs, and improving the quality of production in order to obtain higher production rates. Integrated measures may involve a positive or negative trade-off.

By changing accounting systems at sector and firm levels, it could separately identify environmental costs from overheads and expenditure to underpin real conditions of a firm and/or improve the quality of data and information as a whole (Gray 2006; Khisty 2006; Lovell & MacKenzie 2011). Using data from accounting systems is more credible and trustworthy. These data help lead to comparisons between estimate data and real data with confidence. Thus, Proposition One (**P1**) is:

*P1***:** *There are no differences between estimate (theoretical) and actual MACC models at an organisation level.*

Because they are attractive in both theory and practice, MACC approaches have been part of economic and financial analysis for several decades—with varying degrees of success (Nordhaus 2007). MACC approaches have often failed to meet expectations because of the varying assumptions and theoretical models adopted. As a consequence, MACCs still rely on many assumptions to obtain environmental solutions. To date, their effectiveness has been undermined by various issues such as high cost and weakness of methodologies leading to different results (Löschel & Zhang 2002). Method and assumption flaws lead to limitations in their adoption by sectors and organisations. It is one of the aims of this research to identify obstacles and varying methods to provide organisations with an approach to enable them to easily integrate a MACC approach into their operations to help achieve GHG reductions.

To consider uncertain influences on MACCs from a range of technologies, candidates/users must estimate the probability that due to the specific policy of research, every technology meets the working definitions for success. For some technologies, there are supportive historical data and historical comparisons to learning curves (Yelle 1979). Highly innovative techniques, however, provide only directing data. In such cases, the management of research and development is most often used as an analytical technique to gain the autonomy necessary from experts who are more familiar with specific technologies (Baker et al. 2009; Sharpe & Keelin 1998).

The likelihood of achieving success depends on breakthroughs and what happened with other techniques; these do not offer much to distinguish the findings that are particularly promising. Experts can provide useful judgments about the likelihood that research will overcome particular obstacles. Their judgements can be combined to estimate the overall probability of success for each technology (Howard 1988). This study did not ask experts to provide judgments on what the economic benefits of comprehensive technologies would be because these depend on developments in the economy, such as whether there has been a significant improvement in the electrical grid's regional or national code to transmit electricity over long distances with minimal power loss or using more efficient equipment (Baker et al. 2009).

In anticipation of broader challenges, using energy more efficiently is an important issue in people's lives. This means a critical mass of parallel responses to harsh realities that need to deal with effective carbon pricing standards yearly with more aggressive efficiency. At the same time, the growth and transition to electrification needs development of new infrastructure. Thus, Proposition Two **(P2)** was posed to enhance management accounting by utilising managers and experts to improve MACC methods for managing internal management decisions using cost information on the environment while reducing energy use, as well as emissions. It seeks to identify methodologies to help abate energy use and emissions to develop a MACC approach:

P2: There are no shortcomings in current MACC methodology.

Increased feedback and information about climate change has led to knowledge changes in energy-use behaviour and reduction in consumption (Marcell et al. 2004). Although the research indicated that knowledge is not considered the only element of the decision to engage in pro-environmental behaviour, knowledge does play an important role. People may face difficulties in understanding these issues, which can be complicated by environmental issues, thereby creating significant barriers in education and behavioural change. Evaluating the effectiveness of interventions is important, and needs an assessment of the influences relating to the interventions. It should be noted that there are some important fundamentals of the behavioural changes that must be taken into account such as the acceptance of behaviour change, knowledge and attitudes. Therefore, these elements are important for assessing behavioural changes. The above discussion leads to Proposition Three **(P3)**:

*P3**:** Users' energy management knowledge does affect users' behaviour to change their energy usage.*

A person's position and behaviour are affected by their values, knowledge and understanding (Allen 2012). Often, consideration of attitudes and behaviour are only loosely related to energy use. Allen (2012) sought to analyse more closely the role of attitudes impacting behaviour of energy use. The major objective was to determine attitudes relating to saving energy and discuss how these positions or attitudes can be adjusted. Attitudes are made up of elements of cognition, emotional and functional. They can be evidenced by thinking, as well as individual choices and actions. In other words, a person's attitudes reflect his/her values. A user's knowledge of a particular company may affect his/her feelings (Allen 2012; Moisander 1996; Valkila & Saari 2012). If these attitudes towards more efficient use of energy are to be improved, it is very important that people's quality of life should not be affected by efficiency measures (Steg & Vlek 2009). Amendment to attitudes is a complex field and is dependent on the definition of the concept of "quality of life". The above discussion leads to Proposition Four **(P4)**:

*P4**:** There are no impacts from users' attitudes on energy saving initiatives.*

Individuals' concern for the natural environment is the degree to which people or groups appreciate the importance of the environment and the degree of estimating what they need to do together to obtain environmental values (Bansal & Roth 2000). A number of system designers believe that the main obstacle to users' acceptance of technological changes is the lack of ease in accepting change of new technology. In this instance, new technology is machinery and equipment designed by science, which is constantly redesigned for improvement. Successful adoptions need user acceptance of changes (Davis 1993). Some users of technology stubbornly cling to the belief that new technologies can solve many environmental problems (Kvasny 2002; Van Dyke & Pirates 2003). Most government digital initiatives have highlighted the need to use new relevant technology. One issue with this belief is that it assumes that access to new technology is the main obstacle. However, previous literature has examined a variety of concerns in relation to this issue. The results show that providing access to new technologies for individuals' use is only the first step. For many and varied reasons across industries and communities, the availability of new technology does not guarantee use (Davis 1993). This line of research has also pointed out that the understanding of new technology and acceptance of it after implementation are necessary; benefits from any type of new technology occur through sustained use (Brown et al. 2002). The research uses the term 'public user acceptance' to represent individuals' intention to continue to use new technologies

(Pagani 2004; Venkatesh et al. 2003). Therefore, people need knowledge to accept new technology. Thus, Proposition Five (P5) posits:

*P5**:** There are no impacts of user acceptances of energy abatement initiatives on MACC methodology applied.*

There are many different ways of supporting the many different users in many different scenarios to accept new technology and to achieve a sustainable continuum. Users need access to information in order to gain knowledge and become familiar with new types of technology. For example, organisations could provide presentations, manuals or meetings to discuss any initial problems with extra supervision until employees are comfortable with the new machinery/equipment. Individuals with their own businesses may acquire information by scanning relevant sources on the web such as companies who make new technologies. Such companies may hold external presentations about their new products and include answering related questions. Sales consultants are often happy to visit a buyer and demonstrate their product hands-on. Other ways of acquiring necessary information regarding new technology include periodicals (e.g. the professional sound engineer can keep up with the latest audio equipment by subscriptions to the profession's periodicals that are the first to hear about their field's new technology through advertisements and articles). Colleagues' word-of-mouth is also an invaluable source of knowledge for acceptance of new types of technology (Andersson & Bateman 2000). The use of many sources of knowledge, some of which are mentioned above, could be vital contributions to human behavioural changes (Ashford, Dutton & O'Neill, 1991; Thomas, Clark & Gioia 1993). Thus, it is expected that beliefs in and acceptance of technology are antecedents to attitude, knowledge and behavioural changes. Attitude is a function of the product of beliefs and behavioural results' evaluations. A behavioural belief is the possibility that personal behaviour will lead to a certain result (Mathieson 1991). Consequently, utilitarian specific results become, to some extent, a system that will be used to save time compared to current methods. This evaluation is to assess the desirability of results.

A small number of research projects have studied behavioural changes that led to reductions in energy use in firms and sector. Siero et al. (1996) have studied employees' energy conservation in firms (i.e., behaviours that can be involved in reducing consumption). The employees were set goals to reduce energy consumption. Feedback was received from both individuals and groups. Although they did not identify the actual energy savings, they reported a significant reduction in energy wasting behaviours by workers. Specifically, staff turned off computers at night, turned off lights when they were not in use, reported inefficient compressed air equipment, and disconnected electrical appliances when not in use. The project costs were insignificant, except for slight costs relating to providing the feedback (Ezra M. Markowitz & Doppelt 2009). Most importantly, concerned staff with environmental knowledge saved more energy than unconcerned staff with little or no environmental knowledge. The latter followed the reaction of their groups' behaviour. This highlighted the importance of the role of social influences on the behaviour of energy users.

3.6 Chapter summary

The design of this study includes the research questions, theoretical framework and propositions. A mixed method approach for data gathering includes quantitative and qualitative to achieve the results of the study. Theoretical MACC and actual MACC are defined to explain the methods and assumptions that are used by firms to reduce energy use, as well as GHG emissions. The framework includes constructs that have a significant impact on emissions abatement and specific to organisations. This chapter develops propositions on the basis that human behaviour is likely to be useful in explaining accounting assessment of energy use and emission reductions. Based on the framework of this study, five propositions are stated. The following chapter (Chapter 4), details the research methodology employed to address the propositions and thus the research problem of this study.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

This chapter details the research methodology used in this study to answer the research questions and test propositions discussed in Chapter 3. Quantitative and qualitative methods were adopted. Data were collected via historical records, interviews and survey instruments. A variety of statistical and content techniques were used for data analysis.

4.2 Mixed approach and strategy of triangulation

Truth is relativism and beliefs about the nature of reality on a philosophical base presents differently to various researchers. This relativism also applies in terms of designing questions and answering these questions for the application of science and the theory of knowledge (Morgan 2007).

In the past few decades, differences have emerged between research fundamentalists relating to qualitative methods and its counterpart, quantitative methods, to incompatible discord. Agreement between the two methods was seen as impossible. Academics expressed the need to have allegiance to the traditional discipline of thought regarding the two methods, or accept combining the two methods in academic research (Morgan 2007; Tashakkori & Teddlie 2002). Purists of these approaches consider these methods for higher research, that is, '…implicitly if not explicitly, it calls for the incompatibility thesis.' (Creswell 2008; Johnson & Onwuegbuzie 2004).

Quantitative 'fundamentalists' follow a positive approach in building the theory of knowledge to consider social observations that can be treated as entities in a similar way that physical scientists treat physical objective facts. Supporters of this approach have utilised it to take advantage of statistical and mathematical procedures to predict, control, describe, explore and explain social observations (Johnson et al. 2008). Fundamentalists also claim that an amount of generalisation is possible and desirable in research. Objectivity and methods of deduction is a major hub of fundamentalists. Even in their tactics in the description of writing and the development of social laws, fundamentalists must follow the passive personality of a researcher and must use technical terminology (Creswell 2008; Johnson et al. 2008).

On the other hand, qualitative structural 'fundamentalist' takes advantage of an 'interpretivism' approach when building a theory for research. They reject the social situation 'positivism' and the traditional use of the scientific method (Onwuegbuzie & Leech 2005). Constructivism and humanity, postmodernism, relativity, and interpretation of excellence in research are related to this approach. Fundamentalists of a qualitative approach fully consider the trade-offs between causes, consequences and generalisations impossible and undesirable because the only source of truth is the knower. Unlike purists of quantitative methods, purists of qualitative methods characterise details from their research by a direct inductive (i.e. logic generalising to produce a universal claim or principle from observed instances) basis which, to some extent, could be described as an informal basis (Creswell 2012).

Although quantitative and qualitative models differ in many ways, they both have advantages and disadvantages. Both approaches address research questions by using experimental observations and diagnostic methods to verify data and find meaning in terms of social phenomena understanding. They have more similarities and differences that can also be complementary; therefore, the time is coming for each of the models and approaches to mix and coexist (Creswell 2008; Denscombe 2008; Onwuegbuzie & Leech 2005). In this regard, Creswell (2009, p 3) says that both models should not be seen as polar opposites or binaries; instead they represent different endings on a continuum. Mixed ways are not always socially sound when investigating or combining 'traditional survey' qualitative 'observations and interviews' and quality models that respond to questions using only one technique or approach (Johnson et al. 2008). These approaches involve both deduction and induction, and describe the collective (Morgan 2007) in the pursuit of knowledge for discovering truth. This method is known as 'pragmatism' and follows the philosophical logic in the discovery of cognitive effects. This form creates a range of research that leads to a similar force by using both approaches independently coexisting (Creswell 2008; Denscombe 2008; Onwuegbuzie & Leech 2005).

Mixed method is trying to bridge the distance between the two approaches. It considers strategic research value, and provides data with the richness of a better understanding of research problems (Creswell 2008; Denscombe 2008; Onwuegbuzie & Leech 2005). Newman (2006, p 149) stated that 'it is better to look at something from several angles than to look at it from only one way'. It can be claimed that the mixed research method provides more holistic viewpoints and more adequate illustrations for the phenomenon under examination. Mixing quantitative and qualitative approaches allows triangulation of results (Newman 2006; Thurmond 2001) that could address a number of problems such as validity and reliability usually associated with social research, and reduces the likelihood of bias (Johnson et al. 2008; Morgan 2007).

A significant issue with the triangulation of results is how and when the integration of quantitative and qualitative methods happens. The two methods can mix either by conducting simultaneously or sequentially. For this study, three types of approaches have been used: historical data, quantitative and qualitative. In implementation, one approach can be emphasised over another, depending on the relative information in the study and the study's different stages (Creswell 2009; Onwuegbuzie & Leech 2005). Creswell (2009) combined study methods by dividing them into six main strategies based on four factors: mixing, weight, timing, and theorising. The six strategies are:

1) sequential explanatory strategy;
2) sequential exploratory strategy,
3) sequential business strategy;
4) concurrent triangulation strategy;
5) concurrent strategy an integral part;
6) concurrent transformative strategy.

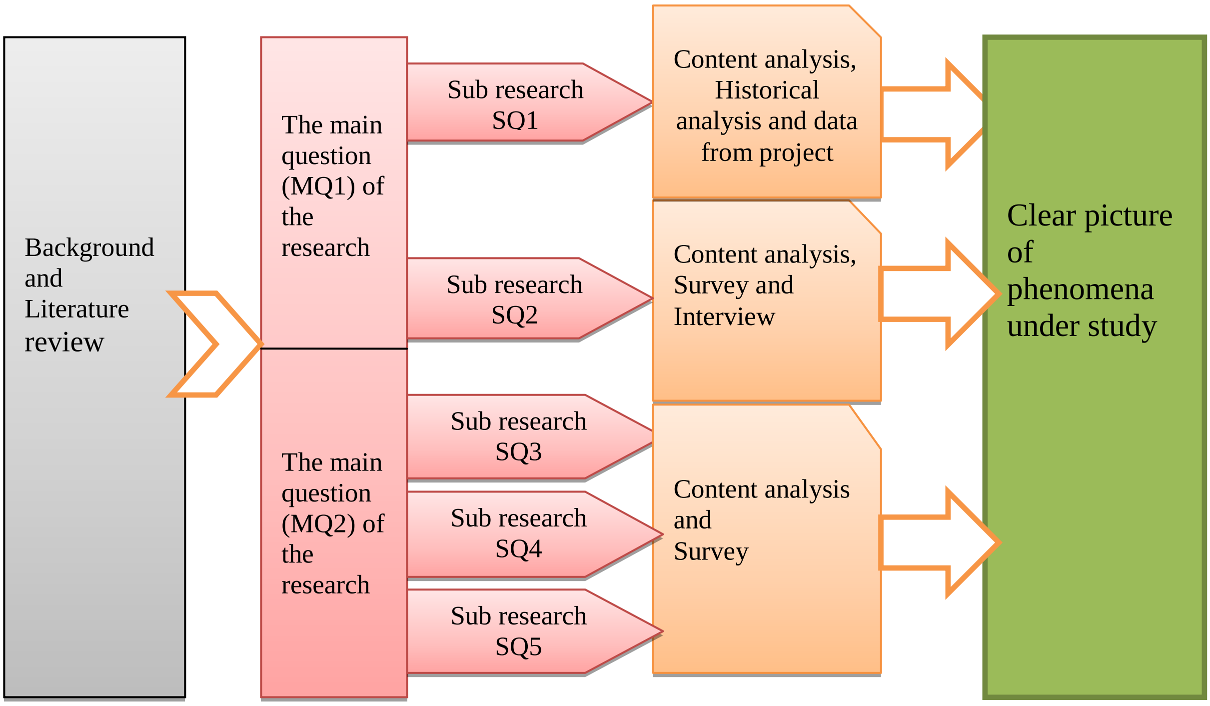

Figure 4.1: Triangulation strategy of this research

Figure 4.1 shows the triangulation strategy used in this study. It shows the use of previous studies (literature review) relevant to this research; then two main research questions were inferred from previous studies to be answered by sub research questions. Furthermore, Figure 4 shows a variety of methodologies that are used to collect data to gain a deeper understanding. Triangulation is achieved by using three sources of research data available; and is thus used to cross-check and confirm interpretations. This study used three sources of data: survey, experts' and managers' interviews, and historical data. Triangulation analysis consisted of content analysis of interviews, surveys and statistical analysis of historical data.

4.2.1 Quantitative approach

Quantitative methods emphasise the measurement and analysis of causal relationships between variables. Supporters of quantitative methods claim the quantitative method is free of personal values. Critics of this approach claim being value-free makes it impossible to rely on the quantitative method for social science research, and even more so for research into physical sciences. In addition, critics claim that on its own, the quantitative method is rarely sufficient. Quantitative approaches are drawn from the natural sciences; therefore, these approaches are regularly used in the social sciences (Morgan & Smircich 1980). There is a great need to assert the quantitative method of acquiring knowledge via processing of data through a sophisticated quantitative approach, for example, statistical analysis (Morgan & Smircich 1980, p. 498). Patton (1990) has said that this method requires '[t]he use of standardised measures so that the varying perspectives and experiences of people can be fit into a limited number of predetermined response categories that are assigned numbers'. In this study, using statistical analysis in the MACC approach with accurate data leads to considerable emission reductions.

A MACC is a graphical display showing how the additional costs of GHGs increase while emissions decrease (Davidson & Essen 2009). MACCs reflect the additional costs for reducing the last unit of carbon and are upward sloping; any marginal costs rise will show the increase in pollution control effort. Basically, there are three types of options available to mitigate GHGs emissions. Technical options that reduce emissions could be achieved through more efficient energy use: examples are fuel consumption engines and alternative fuels, lower tyre rolling resistance and carbon storage. In addition, behavioural options are important and may provide significant reductions with fewer costs. Furthermore, demand options, which means reducing economic activity, are other alternatives (Ekins et al. 2011). This study chose technical and behavioural changes to supplement and upgrade utilizing a marginal abatement cost curve approach to develop a low greenhouse gas plan.

Quantifying the cost-effectiveness of AU$/t CO_2 equivalent for each abatement action is important. The essential costs and benefits should be quantified, as well as the period of costs and benefits which should be determined to be able to calculate the net present value (NPV) (Figure 4.2) (Bockel et al. 2012). There are many perspectives about what discount rates should be used, social or private. There is no agreement in the literature on which discount rate is better, but the social discount rate is perceived to be mostly used (Sweeney & Weyant 2008b). This study uses a discount rate of 10% which means it includes a social rate of 3.5% and a private discount rate of 6.5%.

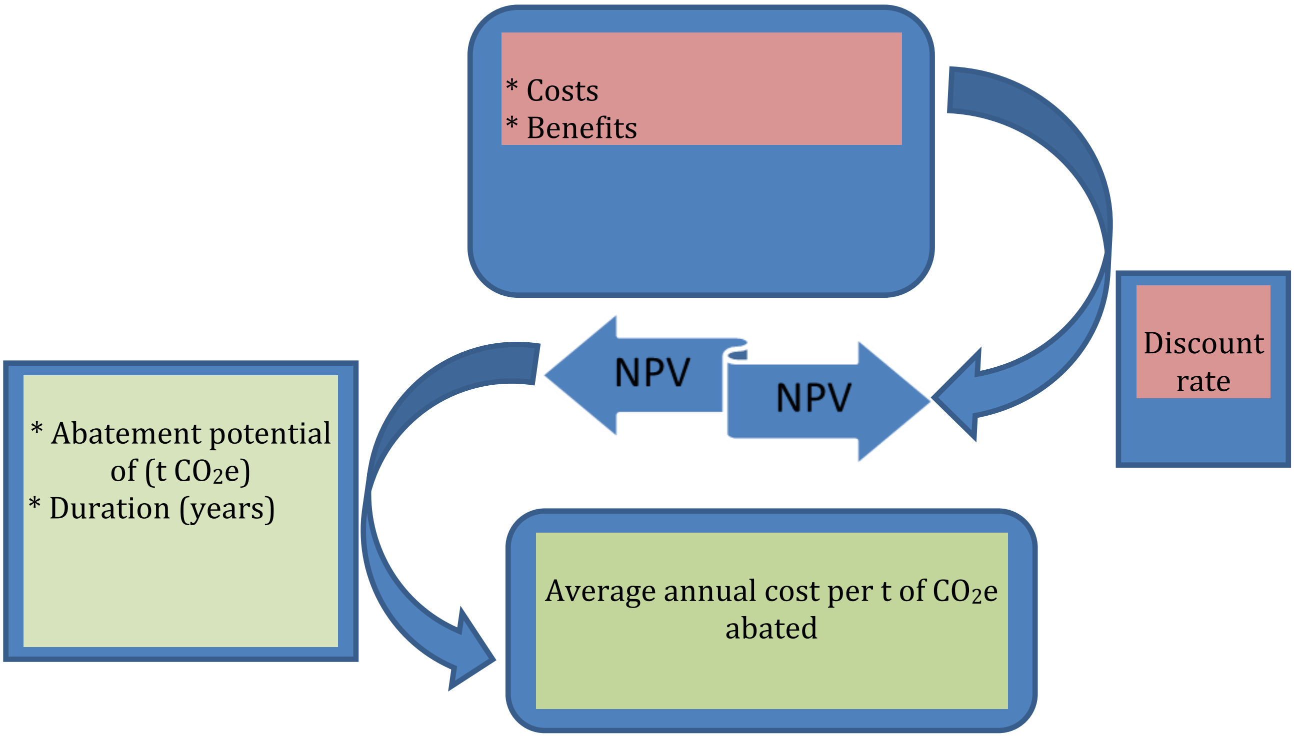

Figure 4.2 From the economic data of a mitigation action to the marginal cost of the action

Source: (Bockel et al. 2012)

However, this discount percentage can be adjusted to reflect rates used to integrate other time preferences. The data needed to build MACCs are calculated according to certain assumptions. To calculate exact costs per ton of CO_2 equivalent reduced, the following formulas are (INFRAS 2006; Riedy 2003; van Odijk et al. 2012):

$$C_{specCo2} = \frac{\alpha * \Delta I + \Delta C - \Delta B}{\Delta M_{CO2}}$$

Where:
Cspec CO_2 = Specific CO_2 equivalent mitigation costs
$\alpha * \Delta I$ = annualized capital costs
ΔB = annual benefits ($)
ΔC = annual costs ($)
ΔMCO_2 = annual amount of avoided CO_2 equivalent emissions (tonne CO_{2e})
The capital recovery factor alpha is determined by the following formula:

$$\alpha = \frac{r}{1-(1+r)^{-L}}$$

Where:
α = capital recovery factor
r = discount rate
L = Lifetime in years

Costs and benefits are taken into account costs, as well as additional revenues resulting from the project. These are compared to the reference situation base, where nothing is done about reducing GHGs emissions. A number of methodologies (IEA 2009) have used NPV delta or change, which is the difference between the NPV of the project or intervention and NPV for the reference case. However, it is supposed that the reference case is not fixed and changes occur, which have implications for costs and benefits over time. The formula for calculating the marginal abatement cost is:

$$\frac{\text{NPV of the project} - \text{NPV of the reference situation}}{\text{GHG emissions in the reference situation} - \text{GHG emissions in the situation with the project}}$$

This method is often used for policy analysis. However, the actual option value for investing in an abatement project should include the strategic value of an investment, along with the usual NPV which has been estimated (West 2012). Mitigation potential can be defined as the difference between the size of the emissions baseline scenario (business as usual) and the level of emissions after application of the reduction mechanism (Kesicki & Strachan 2011). Based on these principles, International Performance Measurement and Verification Protocol (IPMVP) provides four different choices for the measurement and verification of savings. All four options use the following basic formula:

Savings = (Baseline Energy – Reporting-Period Energy)

Corporations use their own methodology to calculate energy use in the baseline in a given year. The baseline period is the period of time selected to represent the operation of the facility or system prior to the implementation of energy conservation measures (ECMs). This should be obviously understood by the customer as part of a Measurement Verification (M & V) plan. The energy reporting period represents actual energy use at the facility as determined by the results of measuring a certain period and the verification report. This is the foundation of energy used during the baseline period without amendments. This period could be as short as the time required to measure the amount instantaneously fixed or long enough to reflect one full operating cycle of the system or facility with variable operations.

Adjustments are made to a baseline of material facts about energy tariff governing properties within boundaries of the measurement equipment. There are two basic forms of adaptation: adaptation routine and non-routine adjustment. For the purpose of this study, the routine amendment refers to factors that routinely change, for example, weather (lighting, heating and cooling degree day), domestic hot water use, and occupancy. Different techniques could be used for independent variables (constant values simple to more complex mathematical approaches). These changes throughout the reporting period and, in the case of different types of buildings, represent the marginal abatement costs on the y-axis against the emission reduction level on the x-axis. MACC points out the marginal abatement cost, but can also be used to identify the average cost and the total abatement cost by calculating the integral.

4.2.2 Qualitative approach

Quantitative and qualitative research methodologies are two philosophical traditions that support the perspectives of positivism and interpretivism in social research (Miles & Huberman 1994). The researcher's option for one methodology over another improves methodology for theoretical and philosophical themes. In practice, this is best appreciated when it is recognised that there is disagreement about the existence of social reality proposals (Glaser & Strauss 1967). This does recognise and consider how different perspectives affect research all over the world; how researchers prove the truth of their claims; and how different proposals around the world and social views on the methods of data collection influence the facts (Glaser, Barney G 1992). In response to these considerations, social researchers, consciously or otherwise, have used different logic, models, and methods in their investigations; consequently, different results can show basic assumptions (Taylor & Bogdan 1984).

As a result, qualitative and quantitative researchers have differences in philosophical foundations, properties, and techniques. These differences show discrimination as a continuum rather than division (Berg 2004), which makes it suitable to some investigations and inadequate for others (Lofland & Lofland 1995). Burns and Bursn (2000) have provided an interpretative approach based on qualitative research methodologies. This is based on the understanding of a social basic conceptual framework for some studies that individuals interpret to create meaning and understanding in their everyday normalcy of life—as pointed out by Burns and Bursn (2000).

Qualitative research has been characterised by certain distinctive features. For example, stresses on the natural environment are a direct source of data; and how the researcher presents a particular context of the direct source of data (Yin 2009). Unlike non-respondents who stand apart from group activities being investigated and avoid all forms of group association, previous researchers were determined to control such activities. This focus on the quality of the research reflected a quest for accurately capturing the meaning of groups' views. It also facilitates an understanding for researchers to shed light on internal, less obvious dynamics of cases (Taylor & Bogdan 1984). Research quality depends on giving first priority to identifying context of physical descriptions from direct first person accounts provided by participants themselves (Strauss & Corbin 1994). While qualitative studies exhibit these quality characteristics in varying and/or acceptable degrees, participants' observations and in-depth interviews tend to be the preferred data gathering method (Charmaz 2006).

Qualitative research reflects the concerns of researchers and the processes that lead to results, but not results alone. The qualitative research analysis needs to reflect and focus on the holistic interpretation of the study's concept (Burns 2000). The design and procedures can be modified according to the study's progress. Good questions that use a qualitative approach are not necessarily very specific. Primary data sources provide bases for researchers to consider a starting point that will initiate a design for data collection (Glaser & Strauss 1967).

Qualitative data analysis is a selective process that relies heavily on the judgment of researchers. Researchers should be comfortable with developments that include making comparisons and contrasts, and having an openness to alternative interpretations of results (Glesne & Peshkin 1992). Qualitative data analysis is the process of organising data. The process is increasingly sophisticated because interpretations of the meaning of facts should be relevant and respect the form and structure of the study (Glesne & Peshkin 1992). The data analysis process is selective, and there is no 'right way'. For instance, metaphors and similes are accepted, as are open-ended questions. Data analysis requires that the researcher should be comfortable with developing comparisons and contrasts. The data analysis process also requires the researcher to be open to the possibilities of previous research findings having alternative explanations or vice versa (Creswell 2008). Another structure for collecting and interpreting data is the case study.

4.2.3 Case study approach

Case studies are tools that adopt varying methodologies (Simchi-Levi et al. 2003). The purpose of using a case study for research is to examine the contemporary phenomenon in the context of a real-life situation (Eisenhardt 1989; Yin 2008). It can be used in research when theories are in their infancy (Benbasat et al. 1987). According to Yusof and Aspinwall (2001), multiple case studies can be powerful evidence for comprehending a study. Case selections are chosen to reiterate and authenticate theory. The case method was promoted in the 1980s as a beneficial method to enhance the accounting field and, despite its limited adoption, it is a means of studying the complexities of regulatory accounting practices (Humphrey & Scapens 1996). Case studies can be qualitative or quantitative or mixed (Yin 2009). The choice depends on the research problem and the aim of the study (Simões & Rodrigues 2010; Yin 1994). Ghauri and Gronhaug (1995) and Leedy and Ormrod (2005) demonstrated how to address issues of validity and reliability through triangulation. Furthermore, they state there is a growing awareness regarding research methods, and growing dissatisfaction with limitations of conventional methods that create a split between quantitative and qualitative ways. According to Yin (2003), the case study research technique has improved over past years, and remains a useful tool to investigate trends and attitudes of specific disciplines of social sciences, especially because of its ability to be used to test theoretical models by using them in real world situations. On the other hand, this approach may not produce quantitative data; however, for this study, it is still included to give some useful pointers and indicators relevant to this study (Leedy & Ormrod 2005; Yin 2003). Furthermore, the case study can help to detail and create a proposition about the research. According to Yin (2003), the case study method provides a more realistic response. Using multiple case studies has great benefits for both internal and external validities (Bhattacherjee 2012).

Case studies can also be widely adopted to implement a variety of methodological options (Creswell 2012). The case study approach was considered appropriate for this research because the issue focuses on a contemporary problem within the context of real life, as recommended by Yin (2003)1992). According to Yin, significant advantages can be obtained from a case study. It provides an opportunity to use a range of tools such as interviews, published and unpublished documents, and archives to obtain ‘evidence’ in order to reveal results. External validity is only necessary, however, if generalisations are to be made from the results of the study (Yin 2003). Creswell (2012) confirms that results from a study should aim to improve understanding of the issue instead of ‘generalization beyond’. Janesick (1994) assumes that there is probably no ‘right’ interpretation in qualitative research, but different interpretations of the same phenomenon. However, by using mixed methods, this study is aiming to provide a universal method for MACCs. The end result is for a MACC to be developed and used as a universal ‘right’ tool for all companies. This means that the same tool can be used by companies universally, therefore, obtaining results that have equal validation because companies are utilising the same methodology that depends on actual information to evaluate emission reductions.

The development of mechanisms and tools for an organisation’s sustainability needs to take into account complex issues and values. Organisations can be more sustainable if tools such as MACCs are used. The natural sciences alone may not be sufficient to guide development in sustainable business management; therefore, the importance of the role of social sciences can be heightened for sustainability policy. This thesis uses the case study of USQ; its processes and drive towards commitment to sustainability decision-making.

In this case study, a number of different sources of evidences have been used, including historical data, document surveys and interviews. According to Yin (2009) and Strauss and Corbin (1994), this helps raise internal validity for a study. More specifically, the organisation’s energy consumption reports for 4 years (2009 to 2012), documents and internal procedures for sustainability management, and interviews with officials in the organisation, such as senior management and staff, were used to improve the methodology of MACCs. It is hoped that benefits from the results of this study case can be generalised for all organisations. It is also hoped that results can contribute to broader theory, and to motivation and commitment to reduce emissions and that the results can be applied to companies in all sectors. For these reasons, it is important that the data collection methods of this study are clearly defined within the framework that extracted data for analysis. This structure can contribute and be applied to future and further studies to improve, refine and widen the functionality of MACCs for business to raise the level of motivation and commitment to sustainability. Therefore, this study used USQ as a case study to obtain specific data.

USQ has developed a reputation as a forward-thinking organisation in energy savings and emission reductions. Moreover, USQ sustainability reports were examined and verified (EPREO 2009). USQ has also been identified as being ‘friendly’ in sustainability commitment by its business partners and other organisations such as Green Building Council Australia and Environmental Planning Agency (GGIR 2009). USQ was selected as a case study for the following reasons:

- Management Direction: USQ leadership has paid much attention to the sustainability management area;

- Reporting: USQ sustainability reports include detailed information;

- USQ uses high quality standards in terms of environmental issues; and

- Openness: the USQ has an open policy that helps in sharing information relating to its sustainability policies and performance;

The Steele Rudd Project supports organisations to understand environmental management practice. To enhance this project, it was built on international knowledge and initiatives that have been developed to provide an opportunity for organisations to undertake GHG abatement projects. Furthermore, these initiatives can contribute to saving energy directly (technical change) and indirectly (behavioural change). This effort is ongoing to provide better understanding for both technologies and management that may be available for organisations to abate GHG. The dearth of research that has been carried out using actual data on the adoption of these options was noticed in the literature. Thus this study was designed to investigate energy use and emission by using actual information obtained from Steele Rudd Project. The project is based on three major buildings of the Steele Rudd College. For the purpose of the study it covers installed lighting for each building with different kinds of light bulbs (see Appendix 8), and installation of three major meters to measure energy consumption during periods of specific weeks; each session was distributed with a survey to provide information about energy and emissions to ascertain the change in residents' behaviour. As a result of interventions in the lighting of various buildings, actual energy savings and emission reductions can be measurable.

4.2.4 Intervention

The methodology was used to collect and analyse data from the project—Steele Rudd lighting. The trial case study first installed meters for buildings F, H and I. The meters read the energy consumption of lighting for the buildings (each half hour was recorded). There were three rotations for each building. The first rotation was without any changes or interventions. The three buildings used T8 lighting. Block F: The second rotation remained with T8 lighting; Block I: The second rotation changed to LED lighting; Block H: The second rotation changed to T5. Block F: The third rotation remained with T8 lighting; Block I: The third rotation changed to T5; Block H: The third rotation changed to LED. The Lux meter was read for each rotation. The distribution of the questionnaires was to assess behavioural changes of residents residing in Blocks F, I and H. Each distribution was maintained during each rotation (see Appendix 8).

- 1st Rotation F Block (T8s) female occupants 20 days
- 1st Rotation I Block (T8s) male occupants 20 days
- 1st Rotation H block (T8s) female occupants 20 days
- 2nd Rotation F Block (leave in T8s) female occupants 20 days
- 2nd Rotation I Block (change to LEDs) male occupants 20 days
- 2nd Rotation H block (change to T5s) female occupants 20 days
- 3rd rotation F Block (leave in T8s) female occupants 20 days
- 3rd rotation I Block (change to T5s) male occupants 20 days
- 3rd rotation H block (change to LEDs) female occupants 20 days

4.3 Ethical issues

In any research, researchers must protect participants involved in their studies from any damage or negative consequences associated with testing in terms of any ethical issues (Creswell 2009; Kajornboon 2005). These measures protect the safety of participants and researchers alike. In this regard, the University of Southern Queensland (USQ) policies and regulations require students to apply for ethical clearance before the start of any research involving humans or animals. This research relied on human participation so approval was obtained from the Chair of the USQ Fast Track Human Research Ethics Committee (FTHREC) before the survey was administered. (Reference No. H12REA047). The researcher followed the guidelines in order to ensure that the survey did not jeopardise the participants in any way in terms of humiliation, safety and/or privacy. Participation was voluntary and the survey confirmed anonymity and confidentiality of participants.

In providing an explanatory statement to participants, it aimed to ensure that all participants understood the purpose of the study in the same way. Fowler (2008) has clarified focus, purpose, and/or ethical requirements of the research ensures reliability and credibility of the data collection from participants. Participants also tend to be more trustworthy in their responses to certain questions and results from data become more reliable (Fowler 2008). Furthermore, in avoiding bias, the role of the interviewer is to encourage participants to answer from their own perspective, attitudes, knowledge, and experiences; otherwise, the researcher would not include responses of participants (Neuman 2005). During interviews, all participants had the right to respond or not to respond to any question/s, and also the right to request tape recording to be stopped at any time. Some questions asked of participatory experts needed to be answered to develop MACC methodologies (Appendix 3). There are several methodologies often indicated that are relevant to developing MACCs, including Expert-based, Model-Derived, Top-down and Bottom-up (Mark Jaccard 2003). These four major methodologies can be considered in deriving and testing MACCs, interaction of abatement measures, emissions reduction from technologies, reflecting efficiency and analysis measures (Silverman 1985). In identifying measures, there should be close consideration of the types of measures that would be integrated into MACC models (Rentz et al. 1994).

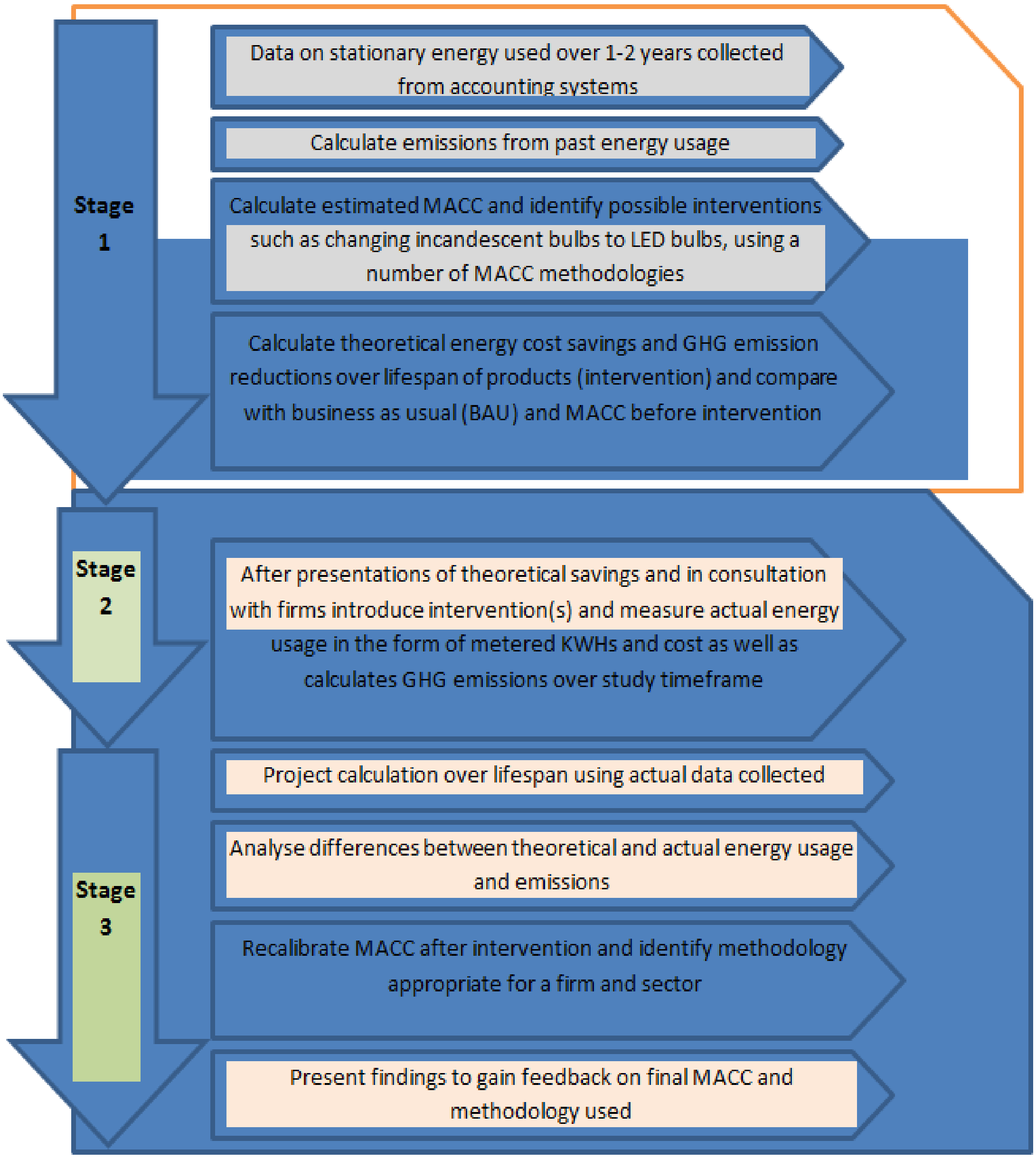

Figure 4.3 Stages for collecting data by organisation

4.4 Data collection and instruments

4.4.1 Historical data

The rationale for historical information is to establish actual data to simulate a model with inadequate GHG policies. Historical data from financial reports and databases (regarding energy consumption and emissions) are used as essentials to ascertain previous direction of energy consumption, emissions and projected costs for MACC. Technological change may be a factor in lowering emissions per unit of output. (Stephan 2010; Taylor 1999). A business as usual (BAU) forecast can become part of MACC by comparing different projects' options for abatement. This also explains the methodology for developing a policy forecast and developing methodology for analysing this forecast.

A MACC provides information about how the actual interventions would operate with different policies. One option is better than another option if it results in better savings and emissions reductions. Case studies reveal how the base policy is practised. This can lead to actual MACC to make practical proposals for saving energy and emissions. There are real projects (Steele Rudd Lighting Trials) for this study that provided some actual interventions to obtain energy and emission reductions. These are reflected in actual MACC.

4.4.2 Survey instrument

The questionnaire used in this study was designed based on research studies by Likert (1932); Marcell et al. (2004); and Fowler (2008). It contained three sections that presented statements and three multiple-choice questions (Appendix 2). The first section contained nine questions. In this section, interviewees were asked whether they were very conscious or not conscious at all in relation to their attitude toward energy conservation; also included were questions about their attitude towards environmental issues and environmental conservation with regard to people's behavioural issues at the executive level (very conscious; not conscious at all). The attitude of respondents can depend on their understanding of environmental information and not necessarily just on information gained through participation. The third, fourth and fifth questions explored whether respondents as a society are acting sufficiently to conserve energy so as to make sure that future generations are not affected; whether they alter their behaviour to prevent global climate change; and whether they consider their active role in the global effort is to curb the problem of rapid climate change (strongly agree; strongly disagree). The statements in the sixth question explored respondents' thoughts and attitudes relating to green issues in regard to considering the importance of environmental issues and respondents' concerns with the issue of climate change. The following multiple choice questions (seventh, eighth and ninth) address respondents' perceptions with regard to electricity consumption, incentives for electricity reduction, awareness about the use of some equipment and users' behaviours in preventing GHG emissions.

In the second section, interviewees were asked to relate their own habits regarding their practical behaviour with respect to electricity use (1 = very conscious; 5 = not conscious at all). Lastly, the questions in the third section explored respondents' knowledge of electricity generation, the greenhouse effect, climate change, and their confidence in their knowledge (1 = strongly agree; 5 = strongly disagree). Composite points were calculated by averaging the scores in each of the Likert-scored categories. Results were analysed according to Marcell et al. (2004) and Fowler (2008). The survey of this study provided information that was used to identify users' acceptance of technical changes. This information was used as a reference to clarify intentions for the future. An example is that firms may have to measure and report internally and externally. This study's survey aimed to obtain a relevant description of behavioural trends and attitudes through opinions of users who were also the study's respondents (Creswell 2009; Newman, 2006).

To obtain a sample for this study, the researcher contacted residents across Steele Rudd College at USQ, Toowoomba who were approached and asked to answer survey questions. This resulted in 42 students (126 surveys) who agreed to participate in the surveys; the questionnaires were distributed to them in rotations accordingly. In each rotation of 30 persons (30 valid questionnaires out of 42), the respondents were asked to participate in three groups\blocks (F), (I) and (H). After removing incomplete or incorrectly completed surveys, 90 valid returned surveys remained. Five issues were addressed after each intervention during this trial. The surveys were issued to students in hardcopy at the start of this study. This procedure was considered the most effective and efficient way to measure attitudes, behaviour and knowledge—and is direct. After this survey instrument was completed, eight experts were interviewed and answers were used to develop MACCs.

4.4.3 Interviews

Miles and Huberman (1994, p. 16) stated that there are '…few agreed-on canons for qualitative data analysis, in the sense of shared ground rules for drawing conclusions and verifying their sturdiness'. Qualitative approach is a measurement method to gain a deeper understanding of the subject. This approach is usually used to find the meanings behind a particular phenomenon or to investigate new topics (Creswell 2013). Qualitative measurements are mostly contrasted with quantitative measurements. Both methods of research are complex, however, qualitative approach usually deals with textual data or words, while quantitative approach is designed to measure and analyse numerical data or statistics. Qualitative research was conducted where participants were included on the basis of personal experience as it relates to the focus of the study (Sawyer & Evans 2010). The search included a specifically investigative strategy based on structured face-to-face interviews. A characteristic of a face-to-face interview is the ability to acquire rich and comprehensive data to give insights and understanding to the value of data (Sweeney & Weyant 2008a).

There are various methods open to the researcher in the transcription and analysis of interview data (Gillham 2000). The study data was analysed using data-based content analysis. For accuracy in the analysis of the data the interviews were limited to managers and experts in developing MACCs. The qualitative data analysis for this research was conducted manually. Codification of data requires a full written copy of the interview. This procedure allows the researcher to know exactly what the interviewee said (Kajornboon 2005). Qualitative data analysis procedures adapted and used in this study are those provided by Creswell (2008) and Neuman (2005). Actions began with writing and organising the data immediately after each interview. Secondly, copies of each are summarised in terms of: 1) the interview guide topics, 2) key issues in the corresponding checklist, and 3) capturing the emerging themes (Miles & Huberman 1994). This was done as soon as possible after each interview, thereby contributing to the accuracy and validity of the data (Neuman 2005). At this stage, conclusions were drawn by identifying closely the similarities and differences, and relations between the concepts in the study. Drawing conclusions involved adopting a strategy ideal type of scale where the indicators used in the research concepts were derived from the literature (Newman, 2006). In spite of Miles and Huberman (1994) referring to verification as part of drawing a conclusion, there has not been a separate verification process for this research. This research used a small number of interviews (8) from managers and experts. This is because the quantity components of the research, interviews, are with limited business experts and managers in firms using MACC.

The selection of participants for interviews was based on those who had experience with MACC. This was an integral part of developing further methodology for using

MACC. Interviewees for the study were selected using purposive sampling, particularly snowball sampling, to supply depth of information to develop methodologies in MACCs (Poorman 2002; Teddlie & Yu 2007). Snowball sampling is used when there is a need to elicit answers from the elements of the population who have a particular character, knowledge or skill (Bhattacherjee 2012; Neumann 1991; Teddlie & Yu 2007). This can help the small sample group of interviewees accept the snowball sampling method for this study; it can also be very successful in the field of research to investigate threads that are difficult to access and can provide the information necessary for the study.

In-depth interviews were conducted with experts and managers. From these interviews, information became available for MACC options and developing MACC methodologies. Thus, a clearer picture was obtained for environmental aims and policies (Appendix 3). According to Richards (2009), these recorded interviews lead to the development of the MACC approach for commitment to sustainability. From the perspective of management and staff interviewees, their ideas identified environmental values of their business. These in-depth semi-structured open interviews also provided a greater understanding of the complexities of the MACC approach. Goulding (2002) and Taylor and Bogdan (1984) believe that in-depth semi-structured open interviews provide more appropriate information than the traditional interview. The next section discusses data analysis, quantitative and qualitative, which includes content analysis research.

4.5 Data analysis

This study has employed both quantitative and qualitative approaches in collecting and analysing data. The data analysis method depends on ways used for data collection. To achieve research results, data needs to be analysed (Collis & Hussey 2009; Saunders et al. 2011). Literature indicates that collecting data needs to be systematic, focused and organised for the purpose of obtaining information from answers to research questions. Analysis of this study's quantitative data from the collection was used for comparisons, which focused on measuring phenomena using the quantitative computer software package, Excel. This study has used Excel spread sheets for this research project to present and analyse the data gathered from the secondary source and from rotations within the energy case study. This program has been used in the quantitative part of the study in order to present the results of the study with respect to propositions that examine the theoretical and actual MACC. It was also used to identify the trend of energy use, as well as emissions. It was also used to compare responses and views of the students (user behaviour changes related to energy use and climate change) that are relevant to the aim of this research in the assessment of behavioural changes.

The qualitative approach is more subjective and focuses on interpreting and examining perceptions and opinions in order to gain deeper understanding for developing MACCs. Qualitative data analysis and interpretation took place in the last phase. A descriptive analysis of the data collected during interviews was undertaken in order to provide evidence for the propositions. Data gathered from interviews are recorded, categorised, summarised and documented (Leedy & Ormrod 2005).

The content analysis method was used to analyse the qualitative data that were obtained from interviewees' responses to questions. Content analysis was employed to analyse interviews. Krippendorff (2012) stated that content analysis is one of the most significant research techniques in analysing qualitative data. Myers (2013) defined content analysis as “the process of identifying, coding and categorising the primary patterns in data”. Therefore, this approach of analysis allows themes to emerge from raw data. In other words, qualitative data analysis is a process of endowing raw data with order, structure and interpretation that transforms qualitative data into important information (Marshall & Rossman 2010). Although, many computer packages such as NVivo and Atlas Analysing are available, content analysis for this study was conducted manually as only eight interviews were conducted. The researcher’s experiences, perceptions, judgement and understandings were involved in interpreting interviewees’ responses.

4.6 Chapter summary

Chapter 4 explains and justifies the research methodology employed in this study. Adhering to the view of methodological appropriateness, the mixed approach was identified as the most appropriate research methodology. Historical data, survey instruments and face-to-face semi-structured interviews were selected as data sources. There was an interview checklist used during interviews. The design of the instrument was closely aligned to the sub-research questions. This research included human ethics, which were explained by clarifying the data collection procedures to management and establishing the rights of participants. The following chapter, Chapter 5, provides an in-depth discussion on the findings of the study.

CHAPTER 5: ANALYSIS FINDINGS - MACC METHODOLOGY APPLICATION AND DEVELOPMENT METHODOLOGIES

5.1 Introduction

This section provides an analysis of the data and analysis techniques and procedures used for both quantitative and qualitative approaches. The analysis of data in this study is in four phases as follows: the first phase is historical data and analysis before intervention. The second phase involves the analysis of trials (actual data) before and after interventions. The third phase is to analyse users' behavioural acceptance of technical change related to energy use, as well as emissions. The final phase is a qualitative analysis leading to the development methodology in the next chapter (see Figure 5.1).

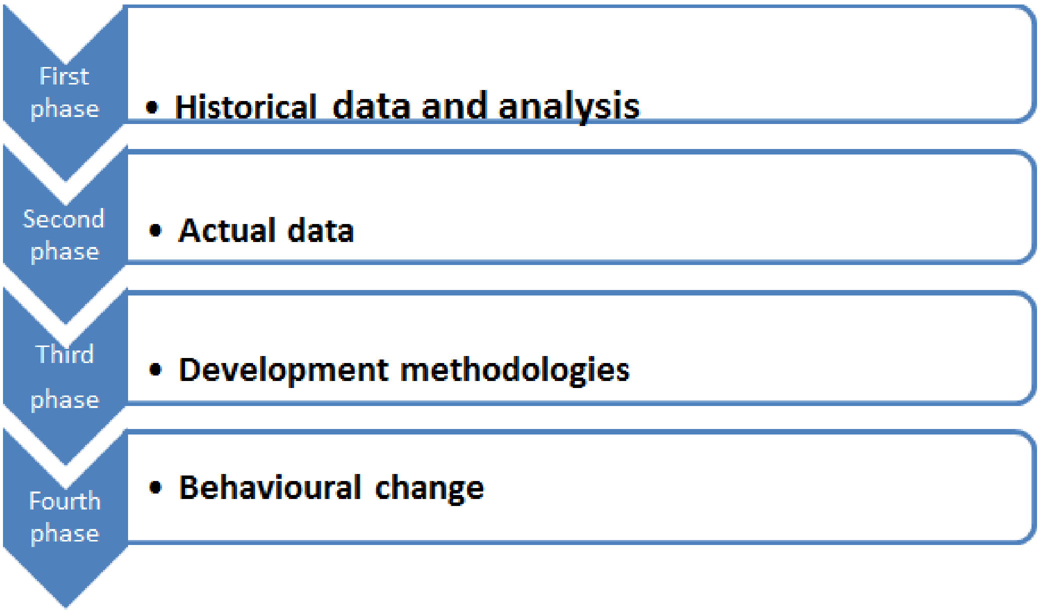

Figure 5.1 Stages for analysing data

5.2 Quantitative data analysis and results

5.2.1 An analysis of USQ data

The results of this research confirmed the notion that there was little attention paid to climate change effects. These findings are consistent with reports of South East Queensland Climate Change and Directory of Queensland EnviroDevelopment projects. In 2009 some local governments were required to submit carbon emissions data in light of the National Greenhouse and Energy Reporting Act 2007. The University of Southern Queensland (USQ) supported many initiatives such as an Environmental Audit of its operations to better understand its environmental impacts in order to be more sustainable.

Trends in USQ energy use

An important first step in responding to climate change is to identify the sources and levels of GHG emissions at USQ, as well as any emerging trends. At USQ, energy consumption, along with greenhouse gas emissions and energy, is a daily process. The following figures (5.2-5.5) show monthly energy consumption for the years 2009-2012.

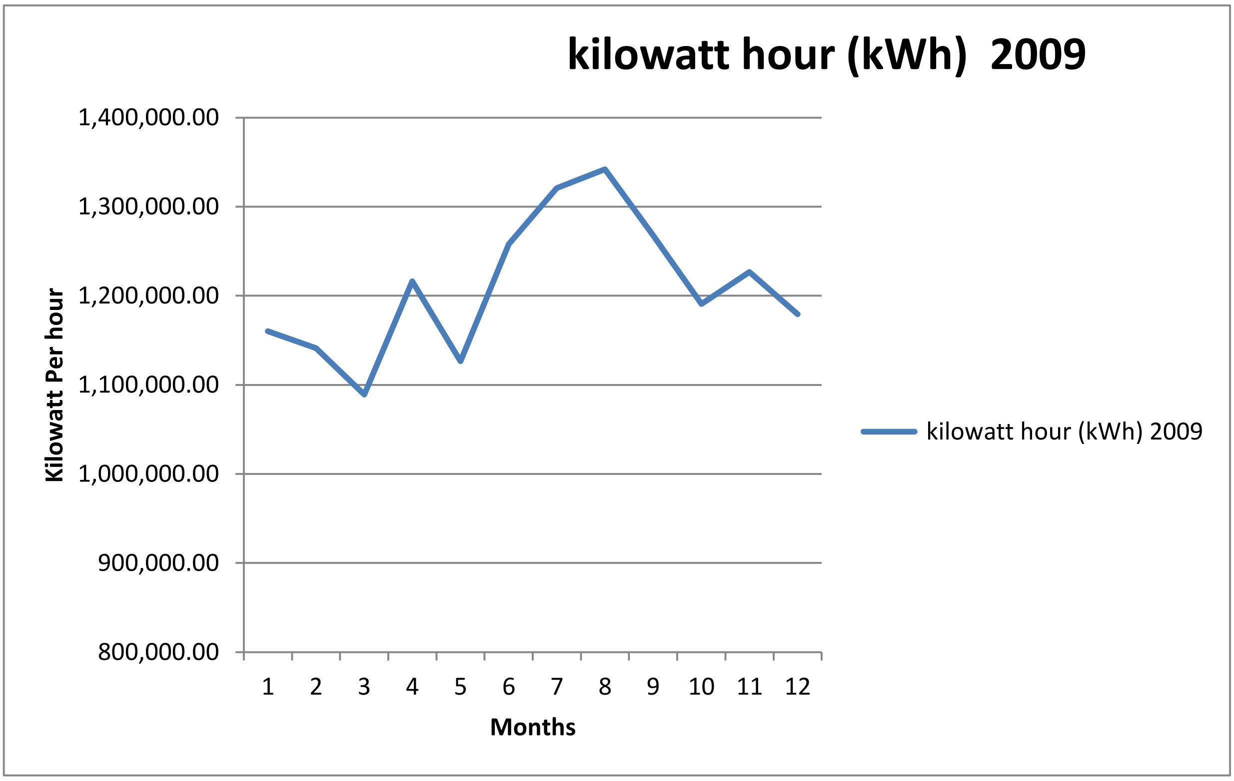

Figure 5.2: Monthly energy consumption 2009

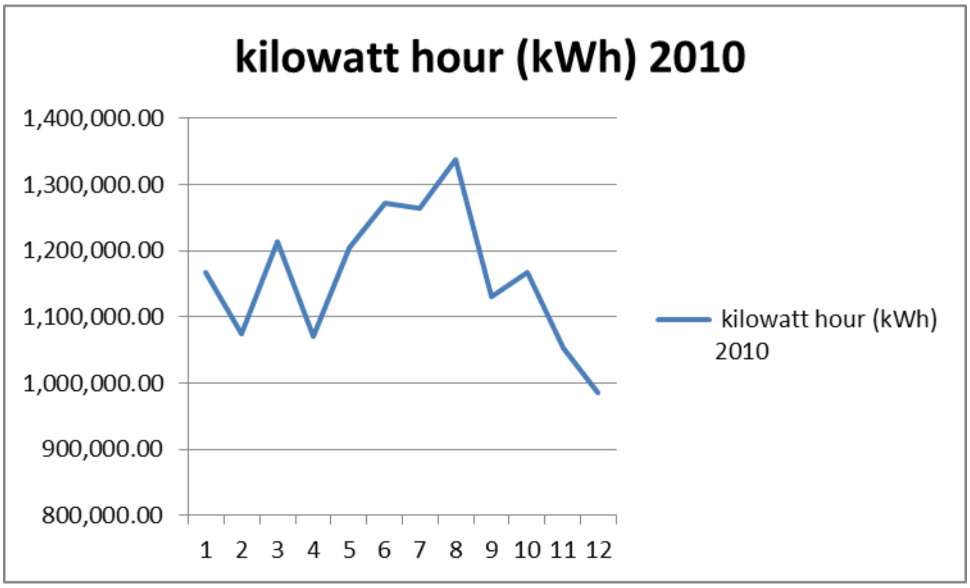

Figure 5.3: Monthly energy consumption 2010

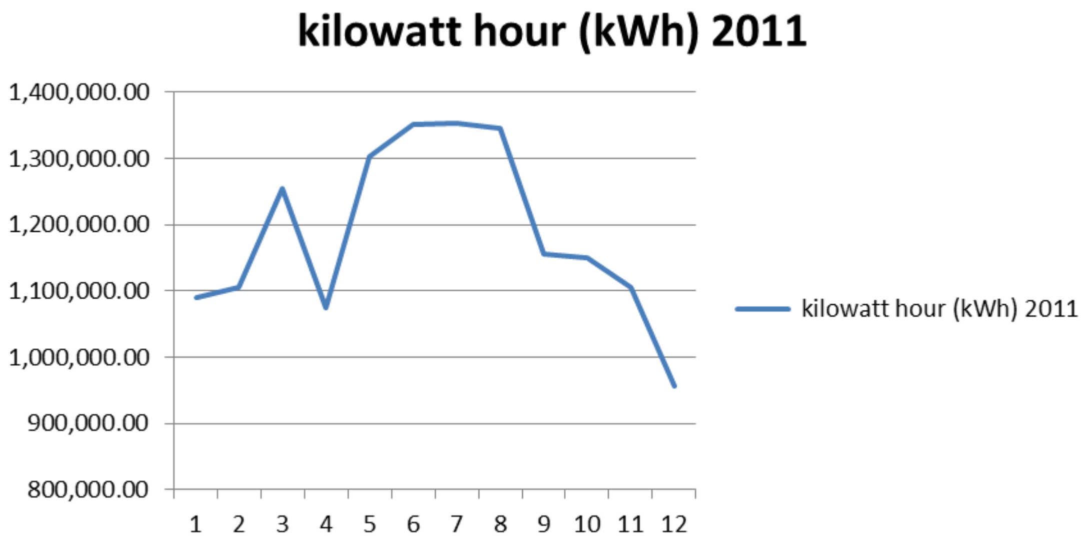

Figure 5.4: Monthly energy consumption 2011

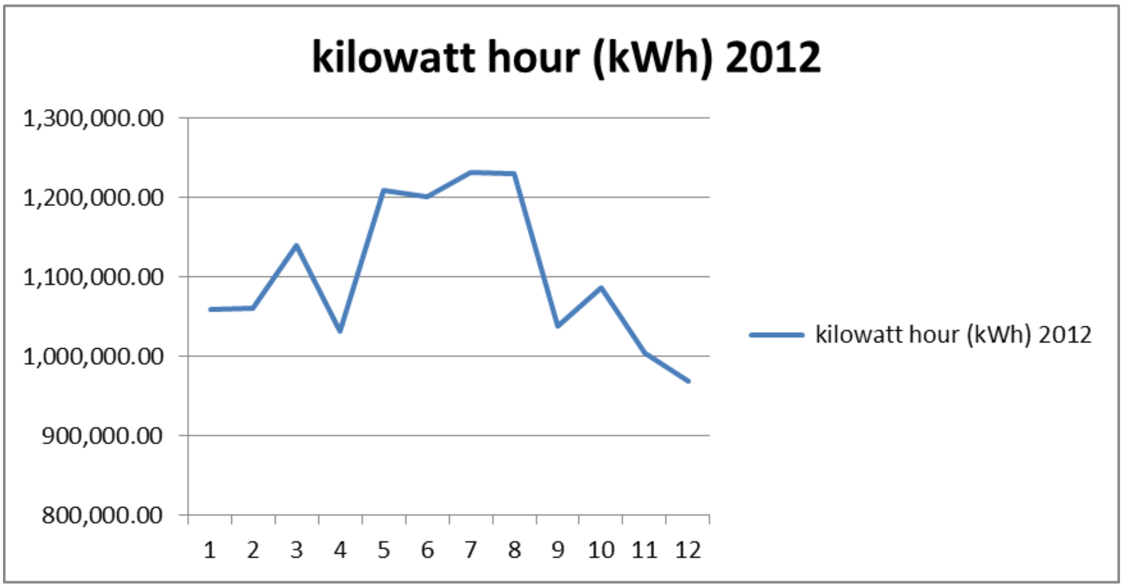

Figure 5.5: Monthly energy consumption 2012

Although the data contains heating/cooling and electrical usage from 2009 to 2012, these are considered the actual usage numbers from electricity bills as appeared in figures 5.2, 5.3, 5.4 and 5.5. The extrapolation process is detailed below in the section data accuracy, as shown in Figure 5.6. Toowoomba campus electrical consumption has remained relatively consistent inconsistent over the last four years. USQ does have a history of focusing on energy efficiency, but there has been a marked increase in attention paid to it over the last few years.

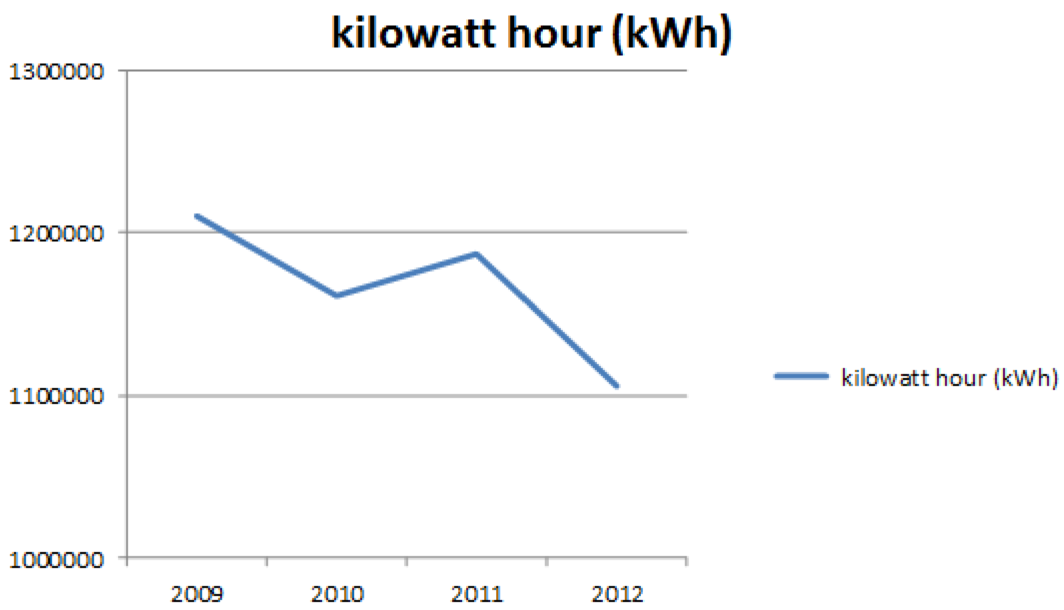

Figure 5.6: Annual energy consumption 2009-2012

5.2.2 Abatement data

Theoretical MACC

USQ has created a strategic plan for reducing GHGs emissions by 2020. This Strategic Plan (2009-2013) is aimed to achieve GHG abatement via an 'integrated campus ecological design layer'. The master plan for environmental transformation is an opportunity to change and transform the existing Toowoomba campus through the implementation transformational sustainability. Among the few available cases, the case study at USQ consisted of three stages to improve cost effectiveness and GHG abatement for USQ Pathways. These stages are:

First stage: Opportunities Report.
Second stage: Feasibility Reports — Investigate feasibilities of individual technologies.
Third stage: Pathways to Carbon Neutrality Report.

Theoretically, a MACC might be used in a similar method (Almihoub et al. 2013c; Jorge et al. 2005) . There have been studies of feasibility at USQ which were implemented in stage two. They excluded abatement from initiatives from purchasing GHG credits and initiatives that have a simple payback of more than 25 years. Thus, they expected a reduction in GHGs emission of about 60% (Riedy 2003; USQ 2011a).

The aim of the Ecological Transformation Pathways to Carbon Neutrality (ETPCN) plan is for USQ to achieve carbon neutrality for the Toowoomba campus by 2020. USQ (2011b) has reported that the results identified that certain strategies were more effective at reducing GHG emissions than others. They (theoretically) found effective results may be achieved from a lighting upgrade to reduce energy and GHG emissions. The plan analysed and predicted energy cuts to calculate the annual financial viability of individual strategies (interventions) and the cost of reducing carbon emissions. The report recommended USQ replace existing twin T8 lamps with single T5 lamps and provide occupancy sensors to low occupancy areas. These interventions are predicted to reduce annual site-wide GHG emissions by 14.5% (1989 tonnes CO_2e/yr.).

The goal of the strategic plan (ETPCN) (USQ) is to achieve carbon neutrality by 2020. The tool (ETPCN) uses emissions inventory data as the baseline to calculate emissions reductions. These are stored in a table (1). At present, the table is set up by exporting data from the (ETPCN) database, but in future it could be modified to contain a direct link to other USQ data. This table is the same as Table 2 in (Appendix 7); the information on the costs and effectiveness of the various abatement measures available is entered through the form (in Excel) and stored. Each abatement measure corresponds to a record in the Abatement table. When entering data into the form, some values can be calculated automatically. For example, when entering a discount rate and the plant lifetime, the capital recovery factor is automatically calculated. Similarly, whenever the capital cost or the capital recovery factor is updated, the annualised capital cost is recalculated. Calculated values can be overridden by entering a new value directly into the field. For example, for some measures only the total annual cost is known, not the raw capital and operating costs. Theoretical emission saved by each option (A, B, C and D) are calculated. To achieve the target of 60% with a discount rate of 10%, producing cumulative savings are 9.50, 17.20, 25.20 and 39.00 thousand tonnes of CO_2e, as illustrated in Figure 5.7.

Marginal Abatement Cost (MAC) Curve Calculator

Discount rate	10%				
Reduction target (thousand tonnes)	60				
Project name		A	B	C	D
Capital cost	$	23,040,000	21,570,000	16,120,000	18,845,000
Annual benefit/cost	$	9,000	54,500	170,300	247,144
Annual average CO_2 savings for project	(tonnes/year)	9,538	7,617	8,089	13,711
Project life	(years)	11	13	8	13
NPV	$	3,006,953	3,641,073	9,649,330	5,859,145
MAC (carbon not discounted)	($/tonne)	29.8	38.2	149.1	32.9
Discounted life savings of carbon	(tonnes)	60,618	53,029	43,154	97,394
MAC (carbon discounted)	($/tonne)	49.6	68.7	223.6	60.2
Cumulative savings for all projects	(thousand tonnes/year)	9.5	17.2	25.2	39.0

Figure 5.7: Details of projects for abatement emission

A MACC for USQ was then calculated and relates particular projections dependant on the above conditions as shown Figure 5.7.

The abatement potential and cost-effectiveness for USQ projects in each option were found according to the method described (theoretical MACC) above. It is also possible to draw a MACC as shown in Figure 5.8, taking options costs into account.

Interesting results from Figure 5.8 are the MACC considered a theoretical calculation and had not been tested. According to this MACC, D project in this case appears to offer more abatement potential at lower costs.

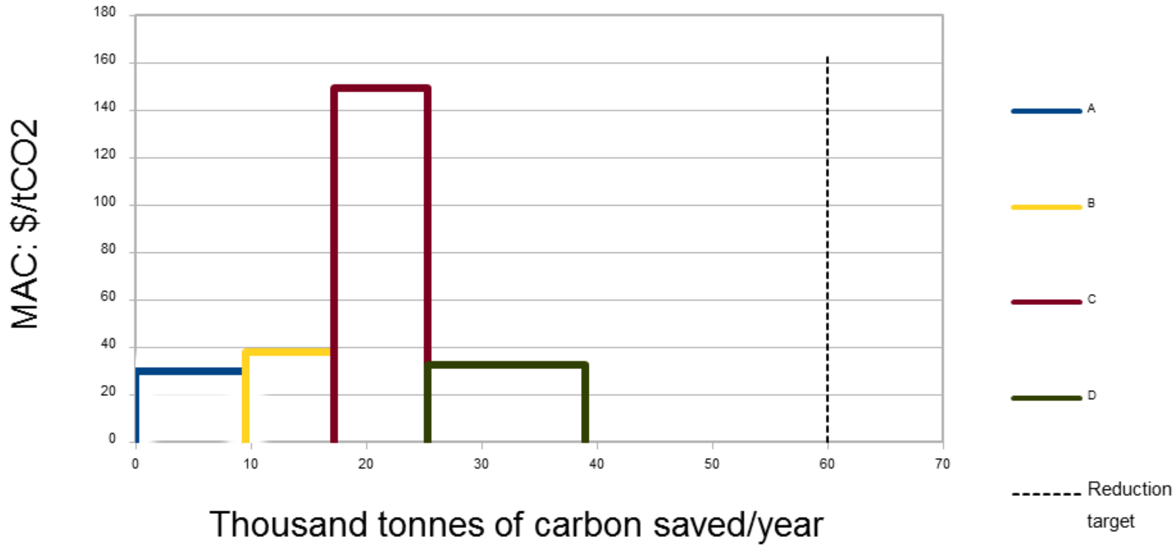

Figure 5.8: marginal abatement cost curve USQ Toowoomba campus 2009

The trend of emissions at USQ and their changes relative to 2009 as baseline year

The several types of GHGs produced by an institution are divided into these "scopes" by the GHG Protocol. Scopes are essentially related to the activities source of the emissions, and are described as follows:

Scope 1 – direct emissions, including any fuel consumed in plant and equipment owned by the organisation such as stationary energy—for instance, natural gas, boilers, generators and mobile (fleet vehicles) that are considered combustion sources.

Scope 2 – indirect emissions - purchased electricity.

Scope 3 – including all other emissions such as air travel, student and staff commuting, and procurement.

USQ undertook many activities in 2011 such as using 10% of its electricity Green Power. During 2010 and 2011, the USQ conducted ecological conversion and a sub-project identified tri-generation photo voltaic and retrofit studies as the most efficient solutions to reduce carbon emissions. Also, some activities related to energy efficiencies and savings were undertaken in 2010 and 2011. Table 5-1 shows emissions relating to energy use; Figure 5.9 shows comparisons of USQ's emissions from 2009-2012 (Scope 2).

Table 5.1 USQ Emissions 2009 to 2012 scope 2

	2009 Baseline(1)		2010 (2)		2011 (3)		2012 (4)		% change
Emission Source	Total Tonnes CO_2e	%of total emissions	Total Tonnes CO_2e	%of total emissions	Total Tonnes CO_2e	%of total emissions	Total Tonnes CO_2e	%of total emissions	Change against 2009
Purchased electricity	13336	80%	12494	79%	13058	77%	12164	73%	-8.79%

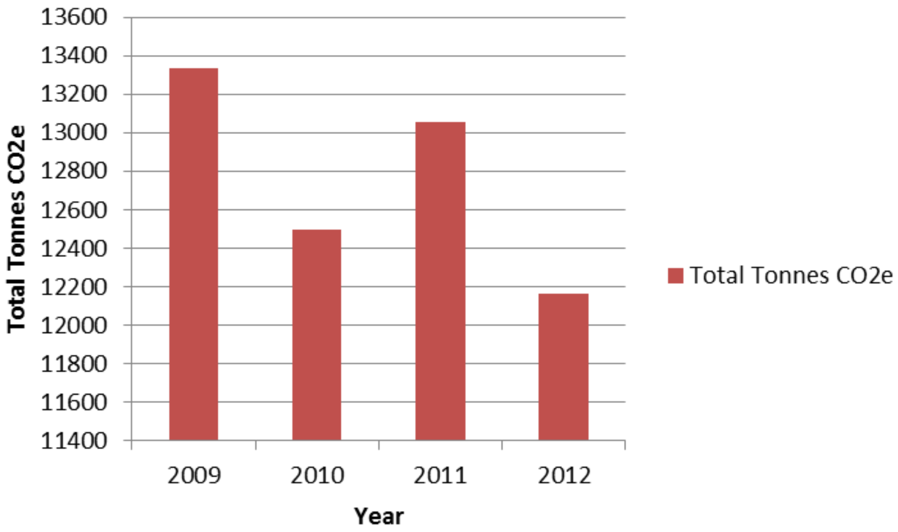

Figure 5.9 Comparisons USQ emissions 2009 to 2012 scope 2

In 2009, electricity was the most substantial source of 13336 eCO_2 emissions at USQ. This total is comprised of kilowatt hours (kWh) consumed by all buildings on USQ's Toowoomba campus where the current electricity provider is Excel Energy (historical data 2009 -2010).

The results confirm that emissions from electric consumption are the highest in terms of quantity in Scope 2, representing 80 percent, 79 percent and 73 percent compared with 5 percent in Scope 1 and 6 percent in Scope 3 for each of the years from 2009 to 2012, as shown in Table 5-2. Table 5.1 and Figure 5.9 illustrate the quantity of the change in emissions over the same period.

Table 5.2 Comparison for USQ emissions scopes 1, 2 and 3 to baseline 2009

	2009 Baseline		2010		2011		2012		% change
Emission source	**Total Tonnes CO_2-e**	**% of total**	**Total Tonnes CO_2-e**	**% of total**	**Total Tonnes CO_2-e**	**% of total**	**Total Tonnes CO_2-e**	**% of total**	**Change against 2009**
Scope 1 (direct activity emissions)									
Vehicle use (diesel and petrol)	351	2%	316	2%	208	1%	400	2%	14.03%
Fuel for Generators	12	<1%	12	<1%	12	<1%	18	<1%	47.08%
Fuel for plant and machinery	10	<1%	27	<1%	10	<1%	30	<1%	202.80 %
Natural gas for stationary combustion	353	2%	436	3%	432	3%	363	2%	2.80%
Total Scope 1	**726**	**5%**	**791**	**5%**	**687**	**5%**	**811**	**5%**	**12.31%**
Scope 2 (indirect activity emissions)									
Purchased electricity	13336	80%	12,494	79%	13,058	77%	12,164	73%	-8.79%
Scope 3 (all other indirect emissions external To the facility)									
Air Travel	543	3%	514	3%	487	3%	556	3%	2.39%
Waste to Landfill	464	3%	464	3%	464	3%	464	3%	0.00%
Rental vehicles	44	<1%	44	<1%	53	<1%	59	<1%	33.16%
Total Scope 3	**1051**	**6%**	**1022**	**6%**	**1004**	**6%**	**1,079**	**6%**	**-0.49%**
Total GHG	**15113**		**14307**		**14749**		**14054**		

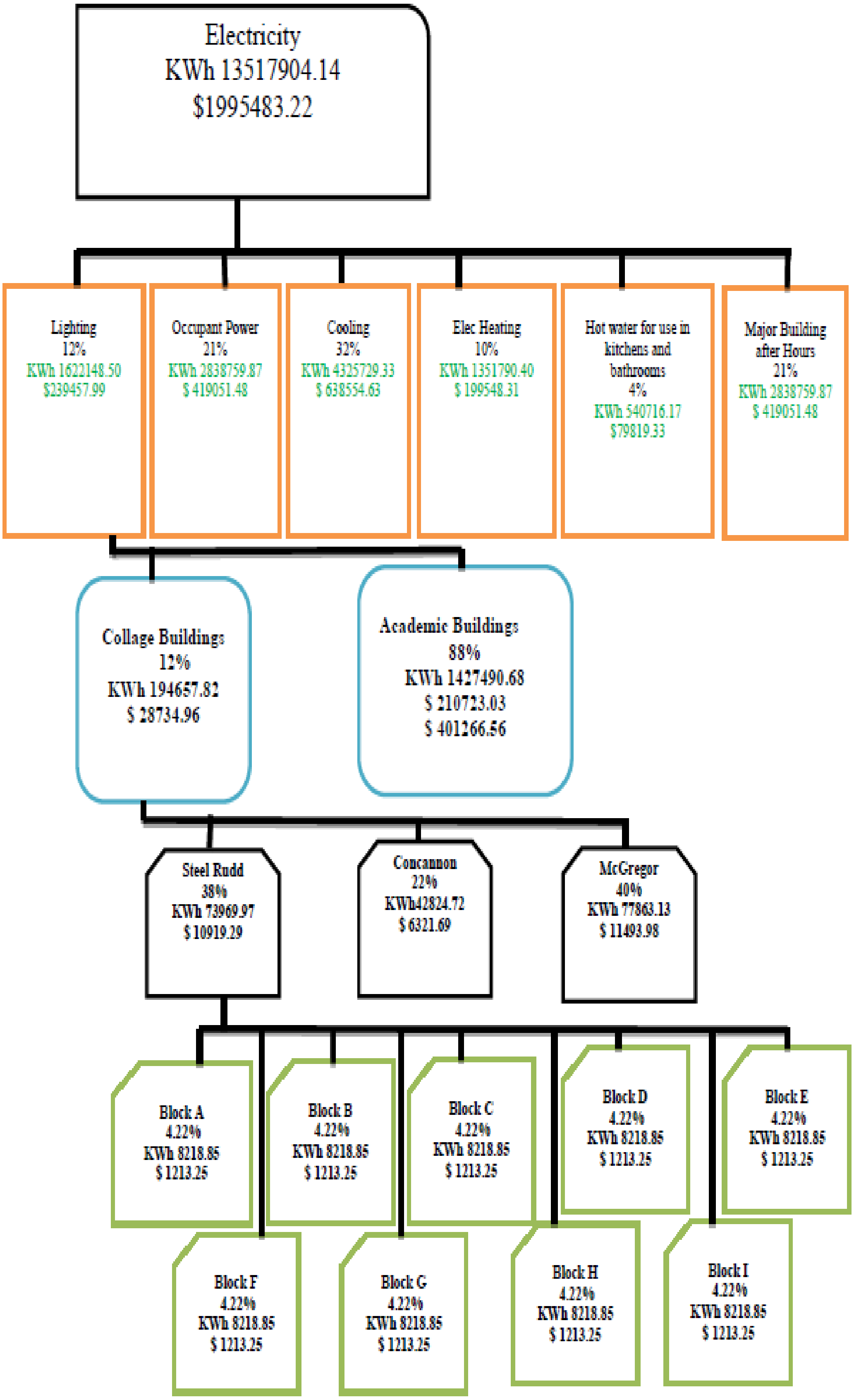

Figure 5.10 Estimating electricity consumption USQ for 2009

Figure 5.10 summarises the estimated annual electricity usage, the cost of electrical use and annual lighting energy consumption for college buildings and academic buildings. Table 5.5 presents theoretical lighting usage (estimating) at Steele Rudd College (USQ). The USQ lighting predominantly uses twin T8 lamps. Figure 5.10 also includes the electricity and key definitions used in the development of this breakdown (USQ 2011b, p. 21; WSP 2012):

> 'Lighting – lighting to the facilities during the standard working day; Occupant Power – All "plugged in" load such as computers, printers and specialist equipment in the facilities during the standard working day; Cooling – air conditioning, including pumps and fans for cooling purposes during the standard working day; Electric Heating – electric heating during the standard working day; DHW – hot water for use in kitchens and bathrooms; and Major Building After Hours – energy used in the major buildings outside the standard working hours.' The estimation and assumption was identified via consultations with experts' panel and electrical contractors.

Actual MACC

The actual data was collected during a specific project period (January 2013 to October 2013) by installing meters (EDMI Mk10E) to measure energy usage in each of three blocks F, I and H at Steele Rudd College (USQ) (Table 5.3). These measurements determined any significant differences in the use of electricity between experimental groups during the case study for this research. The Lux readings used during each rotation verify energy readings in Appendix 9.

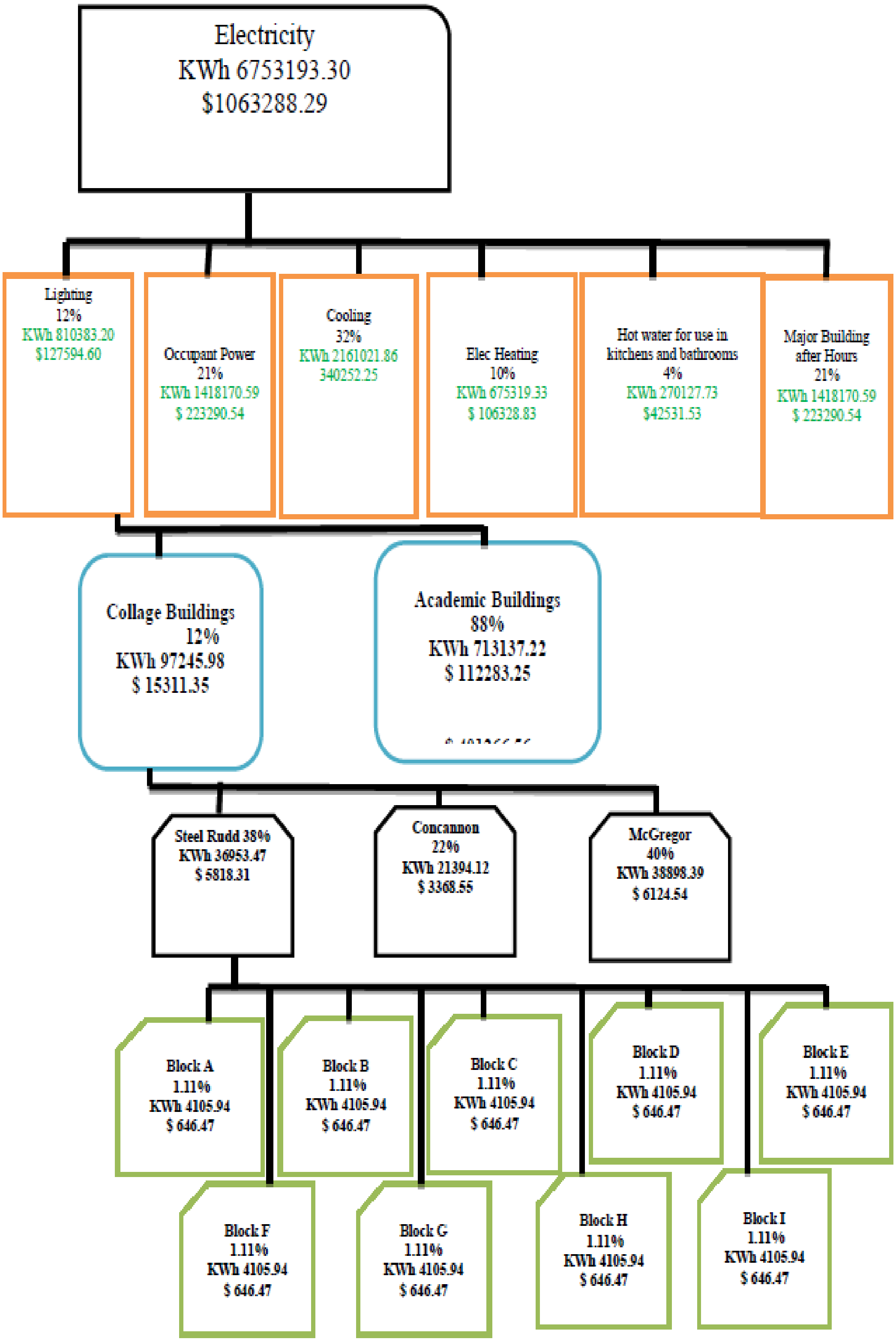

Figure 5.11 Estimating electricity consumption USQ from January to end of June 2013

Table 5.3 Project costs and materials

Materials	Meter Type	Qty		Cost (excl GST)	Product life (hrs)	Product Life (yrs)	Notes
Meter	EDMI Mk10E	3		1,536.48			Purchased 4 meters study used data from 3 blocks therefore adjusted costings back
		Size					
Lamp Type	Wattage	1.2m	0.6m				
T8	36	42	60	253.98	20,000	6	$4.98 for 2
T5	24	40	35	1,800.00	50,000	15	Adaptor and Tube Cost
LED	11	20	0	579.00	50,000	15	T811 = 11w
LED	20	0	14	629.30	50,000	15	T820 = 20w
Labour							
Installation 1st Rotation				$1,660.00			
Installation 2nd Rotation				$635.00			
Installation 3rd Rotation				$200.00			

The estimation of lighting usage table (5.5) is based on figures (5.10 and 5.11). The results of the study reached the following conclusions after doing three rotations. Each rotation was of 20 days—60 days duration in total. First savings in energy use amounted to 954.70 KWh. This was equivalent of 0.855 tonne CO_2 at a rate of reduction of 23 per cent. The total of cost savings was $150 (see tables 5.4, 5.5).

Table 5.4 Blocks details for rotations

Block	Rotation	Occupant	Lighting Type
F	First	Female	T8
F	Second	Female	T8
F	Third	Female	T8
I	First	Male	T8
I	Second	Male	LED
I	Third	Male	T5
H	First	Female	T8
H	Second	Female	T5
H	Third	Female	LED

Table 5.5 Theoretical vs. actual energy usage

	Actual lighting usage			Theoretical lighting usage (estimating)			Differences			
Block	Total Lighting usage KWh	Cost	C02-e	kWh	Cost	C02-e	Usage Savings	Cost Saving	C02-e	Change %
F	416.88924	$65.62	0.37103	456.22	$71.83	0.406036	39.33076	$6.21	0.03501	8.621007
F	264.66972	$41.66	0.23556	456.22	$71.83	0.406036	191.55028	$30.17	0.17048	41.98638
F	193.07616	$30.39	0.17184	456.22	$71.83	0.406036	263.14384	$41.44	0.23420	57.67916
Total	874.63512	$137.67	0.77843	1368.65	$215.49	1.218107	494.01488	$77.82	0.43968	36.09505
I	407.58936	$64.15	0.36276	456.22	$71.83	0.406036	48.63064	$7.68	0.04328	10.6594713
I	245.23212	$38.60	0.21826	456.22	$718.30	0.406036	210.98788	$679.70	0.18778	46.24696
I	180.47388	$28.41	0.16062	456.22	$71.83	0.406036	275.74612	$43.42	0.24541	60.44148
Total	833.29536	$131.16	0.74163	1368.65	$215.49	1.218107	535.35464	$84.33	0.47648	39.11553
H	702.5346	$110.58	0.62526	456.22	$71.83	0.406036	-246.3146	-$38.75	-0.21922	-53.99031
H	426.21264	$67.09	0.37933	456.22	$71.83	0.406036	30.00736	$4.74	0.02671	6.577388
H	314.60544	$49.52	0.28000	456.22	$71.83	0.406036	141.61456	$22.31	0.12604	31.04099
Total	1443.35268	$227.18	1.28458	1368.65	$215.49	1.218107	-74.70268	-$11.69	-0.06648	-5.45813
Total of the period	**3151.28316**	**$496.01**	**2.80464**	**4105.98**	**$646.47**	**3.654322**	**954.69684**	**$150.46**	**0.84968**	**23.251376**

Tables 5.4 and 5.5 reveal the first rotation details of Block F, I and H. Block F's occupants were female; the block's lighting type was T8; and the actual consumption was 416.89 KWh equivalent to 0.37103 CO_2e. The costing was \$65.62 for Block F. Block I's occupants were male; the block's lighting type was T8; and the actual consumption was 407.59 KWh equivalent to 0.36276 CO_2e. The costing was \$64.15 for Block I. Block H's occupants were female; the block's lighting type was T8; and the actual consumption was 702.53 KWh equivalent to 0.62526 CO_2e. The cost was \$110.58 for Block H.

Tables 5.5 and 5.6 reveal the second rotation details of Block F, I and H. Block F's occupants were female; the block's lighting type was T8; and the actual consumption was 264.67 KWh equivalent to 0.23556 CO_2e. The costing was \$41.66 for Block F. Block I's occupants were male; the block's lighting type was LED; and the actual consumption was 245.23 KWh equivalent to 0.21826 CO_2e. The costing was \$38.60 for Block I. Block H's occupants were female; the block's lighting type was T5; and the actual consumption was 426.54 KWh equivalent to 0.37933 CO_2e. The cost was \$67.09 for Block H.

Tables 5.5 and 5.6 reveal the third rotation details of Block F, I and H. Block F's occupants were female; the block's lighting type was T8; the actual consumption was 193.08 KWh equivalent to 0.17184 CO_2e. The costing was \$30.39 for Block F. Block I's occupants were male; the block's lighting type was T5; the actual consumption was 180.47 KWh equivalent to 0.16062 CO_2e. The costing was \$28.41 for Block I. Block H's occupants were female; the block's lighting type was LED; the actual consumption was 314.61 KWh equivalent to 0.28000 CO_2e. The cost was \$49.52 for Block H.

The estimation for lighting was higher than actual lighting in the three rotations. Considerable savings have been achieved regardless of the quality of interventions. The results indicate that the savings increased sequentially from rotation to rotation. Proposition One (**P1**) states that "*There are no differences between estimate (theoretical) and actual MACC models at an organisation level"*. The results indicated that theoretical lighting usage was 4105.96 KWh equivalent to 3.6543322 and cost \$646.47, which was higher than actual lighting usage that was 3151.28316 KWh equivalent to 2.80464 and cost \$496.01. Due to the differences in theoretical lighting usage and actual lighting usage, proposition one is **not supported.**

5.3 Development of methodologies aspects

Qualitative data analysis and interpretation were employed in this study to support the results from survey and data extracted from document reports in Section 6.2. This section (5.3) involves a descriptive analysis of the data collected from interviews and used to investigate and develop the MACCs for firms by using the opinions of experts and managers to obtain best insights to develop MACC methodology at firms' levels.

As stated previously, one purpose of this study was to develop MACC methodologies. From the interviews, the study gained context regarding some of the common drivers in the MACC. The transcripts from the interviews were analysed by organising the information into main themes. This chapter commenced with a broad picture which incorporates general information about organisation energy savings, the targets for emission reduction and their motivations towards CO_2 reductions. The study aimed to identify specific initiatives that are being taken by firms to promote and develop methodology in MACC that could deal with environmental issues. The most important goal of this study was whether experts and managers of businesses are actively involved in their business community in any way, for example, using appropriate ways to reduce the use of energy as well as abating emissions; whether or not they assess and manage their firm environmentally; what methods are being taken to improve MACC for identifying particular energy savings and reductions of GHG emissions; and ascertaining if any social behaviour and other environmental behaviours are involved in their workplaces. The transcripts from the interviews were analysed by organising the information into main themes. The results are displayed in Figure 5.1.

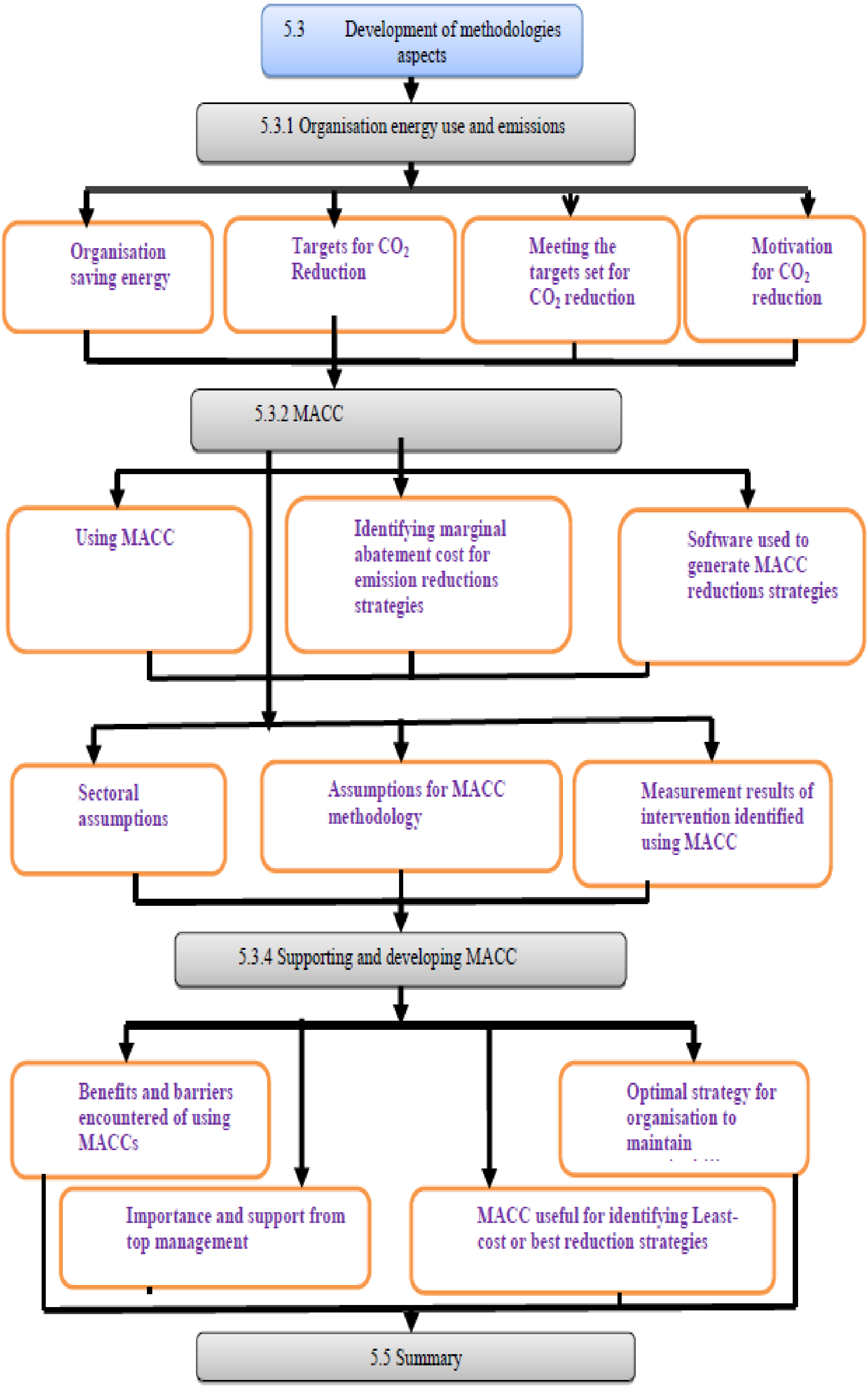

Figure 5.1 Structure of development of methodologies aspects

5.3.1 Organisation energy use and emissions

This research focuses on energy use and emissions reduction. Accordingly, section 5.3.1 presents the findings regarding experts' fundamental views on organisations saving energy, which justifies the focus on firm saving energy. Section 5.3.2 further determines firm targets for CO_2 reductions, which is known as the abatement target. Section 5.3.3 explains how firms can meet their targets. Section 5.3.4 presents what motivations lead to energy use and emission reductions.

Organisation saving energy

It is worth mentioning here that most interviewees practise some kind of emissions reduction within their organisations. The opinions of the experts interviewed for the study differed from each other when asked to name critical points regarding energy savings, reducing overall CO_2 emissions, the need for saving costs and reductions in the carbon footprint. Interviews with experts indicate that most corporates have a strategy for abatement emissions and focus on clean mechanisms and energy efficiency. Overall, experts summarise their answers within three elements as components of the first question, which are as follows:

Reducing overall CO_2 emissions

One of the experts, in relation to reducing overall CO_2 emissions states:

> *The university has taken quite a holistic approach to carbon reduction and energy efficiency and energy reduction as part of that bigger strategy since perhaps 2009 and within the previous strategic plan there was a clear goal to reduce carbon emissions, in fact to be carbon neutral by the year 2020. In 2009 there was a 10% per annum reduction established as a target. So there were a number of things that the university did to specially focus on energy reduction. There were various reviews and energy audits of the buildings, and the buildings were in management systems and that had a focus of looking for plan changes, infrastructure changes as well as housekeeping and operational changes, to looking at control methodology and set points to see if they were too high or too low, looking at the operation of the plan so that it was working in harmony and not conflicting in optimal.*

On the other hand, one of the experts interviewed mentioned that their company tries to achieve good things about environmental issues. Another of the experts interviewed for reducing overall CO_2 emissions states:

> *Basically at this stage, we try to be good corporate citizens where we can, but obviously cost is a good issue where we identify things that can easily be achieved like savings in consumption electricity; we're doing that. At this stage, we haven't really done any major capital works with the aim of emissions but we worked with our consultant engineers and obviously whenever possible we have a data set here in town which is one policy of its type in Queensland where it actually uses outside ambient temperatures rather than generate and cool conditions, so where we can, we are chipping away.*

The need for saving costs

All the experts interviewed in this research had similar views and confirmed that saving costs played an important role in respect to companies involved with any program for reduction emissions. Most interviewees emphasised that their companies try to achieve cost savings. One expert interviewed states:

> *We've also looked at a Para fracture correction for the site and we are just part way through a subject to Para fracture correction devices that would take us from, I think, we're about 10.194 up to 10.198 efficiency which is really good. We've reviewed the lighting standards for the university and they are constantly being updated and your project of course links into some of that work we have previously moved from standards we now have LED technology as well becoming more economically viable. We have installed a significant amount of sub-metering around the campus, we have metered previously but only on a couple of the main incoming points, so it was very difficult to determine where the efficiencies or the inefficiencies were at. Now we've got a better view of that, there is more sub-metering to come. We've instituted changes to the vehicle fleet. The vehicle fleet is either diesel or hybrid—that is the standard petrol is the least desirable or we moved the entire pool vehicles to smaller diesel vehicles in 2009.*

Another interviewee gives examples to explain how important cost savings are for his firm and introduces some projects for saving costs. Amounts of energy use could result in savings, with the expert stating:

> *We've got campus trying heaters which are very fuel efficient using a renewable energy resource. Secondly, hot water accounts for 24% to 25% of our use so therefore that's significantly reduced. Then we got solar power on the roof to account for a bit which leaves us with a bill of about $100 a month for all of our electricity. With respect to other clients, the people we work with, we've just completed a project where over the next 15 years a company has input a new machine and its cost of carbon is going to be $7 a tonne, so that's a significant reduction on where we are at, and saves around about 6800 tonnes of green gas emissions from one machines. The second project we are working on at the moment is how we are helping people to save energy. We have got a saving at the moment and it will produce 5500 megawatts of power and it will also offset 160000 litres of gas by using methane from Chains a minor.*

Motivation for reducing carbon footprint

The lessening of a firm's carbon footprint is one of several ways GHGs can be reduced. Many firms adopt this method as an effective way to deal with environmental issues. As stated by one of the experts:

> *... so the ecological transformation study, which the university did follows in the environmental orbit [and] investigated the feasibility of renewable energy and carbon options for the university to implement to reduce its carbon footprint, and therefore reduce energy; prescribed to purchased electricity by*

far represents the greatest portions for [the] university's carbon footprint so reducing energy consumption is a high priority for the university.

According to another expert supporting this view, a footprint is made, and he states:

With respect to our carbon footprint it has gone right down. We, for instance, only use a B20 diesel income that's been a conscious saving to make sure we use that sort of energy. We got solar panels on the roof and we got solar hot water. So if you look at office heating and cooling, it accounts for about 20% of our energy.

Targets for CO_2 Reduction

In spite of the existing strategies at institutions that experts have worked into their firms, there are some specific targets. One expert alluded to a target of 10 per cent, but the others did not refer to a specific number or per cent—as one expert states:

The university did have an annual target of 10% reduction in each year to achieve that 2020 goal of having carbon neutrality. However, in the new strategic plan, the carbon neutral goal has been taken out so we are restabilising the university's targets. The aspirational goal of being neutral by 2020 has been examined and determined that it may not be necessarily achievable from an economic point of view, given the high cost of the projects required to achieve that carbon neutral status. Currently, the university is still focusing a position around carbon reduction; however, we don't have that former clear 2020 goal. The targets will be revised bearing in mind the balance required around environmental responsibility and economic responsibility.

Some experts say that they have been set specific targets for certain years, but do not intend to focus on ambitious initiatives that would give importance after that and contribute to reducing energy consumption—through practice, it will impose its importance in the future, therefore, one expert states:

The previous strategic plan had a very clear target to be carbon neutral by 2020. The new strategic plan, which I think had a much softer description, doesn't specify a target. It talks about environmental responsibilities; so it had softened the objectivity of that. In some ways I see that lesser statement of the university's commitment, but on the positive side we are now monitoring carbon related performance in senior management and senior government's committees; so three years ago there was no top end oversight to carbon related performance, now there is, and I think that's extremely positive. I think so because everybody wants to see that carbon emission total coming banned; if it starts trending upwards we'll have some tough questions to answer.

Some experts believe that developing goals with ambitious consolidation initiatives contribute to the reduction of energy consumption and could be strengthened by the following examples through practice:

Yes it is, I'm finding all the better businesses that I work with mostly...need to drive this cost out of their business and I find the ones that are doing that are *the ones that are in fact ahead of the game anyway; it's even making them more efficient than the others. About 4 years ago we said that we are going to drive cost out of the business. We already had a car which was a Toyota Prado. A conscious decision was made to replace the car because we are doing a lot of full on driving in western conditions. We changed and we are now driving a more fuel efficient Subaru Forester and we have cut our consumption by 50% just by swapping cars. Overall, with the installation of solar panels for hot water mentioned previously, we've dropped our diesel use by half and our electricity use by 75%.*

On the other hand, some interviewees stated that while they considered energy saving important, they could not identify their targets as a percentage:

No, I just said, today I'm more in heavy industry and more of those constructive-like manufacturing big energy users probably a lot more to that than ourselves, if I were to look at our energy usage I'm sure, I'm not 100% sure, but I would say we would get a percentage of what it would be. Air conditioning and that would be pretty constant in through most places I would think fall closely just general lighting power, I mean it's not like we run a plant as in machinery, or as a manufacturer of machinery or smelters, or anything like that. But there's always changes coming on, like I know we are moving towards KVA tariffs and stuff like that; so that's why we have been working closely with everybody about how to affect correction. Now obviously they came to us. They've got a scheme that they have had for about the last 18 months. It is in the CBD where they have identified the 25 biggest users of power and they've obviously got money to spend, so they came to us to review our current power factor correction with the aim of improving that. They paid 95% of its cost. My understanding is this building is 30 years old, our power factor correction is 0.89 and when finished it will be 0.98. Of course once the KVA tariffs come in, the worse the power factor correction and the more you're going to get charged; so we are chipping away those sorts of things but it just takes time. We've upgraded just recently one of our air-conditioners. The previous one was 20 years old; the new unit is probably half of the size and 4 times more efficient, so hopefully there's significant savings. I haven't seen the first power bill so just hoping that some significant savings will come from that.

The above quotes reflect the importance of drawing targets for companies and the extent of the importance of activities and information in achieving company objectives for reducing energy use and emissions.

Meeting the targets set for CO_2 reduction

Additional action is needed to abate greenhouse gas emissions to achieve the abatement target of sectors and industrial reduction generally. The abatement actions involve cost for firms, and it is important for both companies and decision-makers to be aware of the costs of control.

Overall, most experts who determined their targets exactly have almost achieved their goal, albeit with some difficulties. One expert states:

The university, initially, to achieve the targets of 10% annually, whilst trying to get our projects lined up and funded by the university, purchased green power as an offset option to kick start the reductions to help us achieve the 10% annual reductions. The green power was in the major electricity accounts for the university, so it enabled the university to come close to achieving the 10% annual reduction.

According to the experts interviewed, sometimes they met their target; other times only section targets were met. The experts highlighted the actions that contributed to meeting their targets—as the interviewed expert explained:

I think we met our target in the first two years so that would be 2010 and 2011. And then in 2012 some of our base started to change because we purchased the Springfield campus. This purchase changed significantly the energy profile coming from there, and the other thing is we stopped buying; we had some green power offset in 2010 and 2011 and I believe they stopped in 2012. Now, I know that's not a carbon reduction, but it is an offset in terms of the carbon impact; we separately reported the offset so as not to confuse the data so that we could still see our true performance.

On the other hand, managers who do not determine their environmental goals exactly could not achieve a significant quantity of energy saving or emission reduction.

The next section provides more detail about the motivations to decrease energy use and emission reductions.

Motivation for CO_2 reduction

Indeed, highly motivated people aim to keep abreast of the emission response issues and see themselves as providing capacity building services to motivate other stockholders. Interviewees described motivation as a primary instigator to others to become environmentally friendly. The justification for this was the motivation provided in monitoring individual energy use and awareness of new methods of being *green*. They are aware of the acute threat posed by climate change, but have yet to discover the means or motivation to work towards controlling it. All the experts presented similar views on the separate factors involved in motivating people's attention to climate change and energy saving. One expert who has focused heavily on the personal factors states:

I personally have no doubt at all about the climate change that's occurring. I think anybody in the scientific community really can't dispute that it is happening and that it's happening as a result of human intervention. If the predictions are correct, you know, we have a very limited window to do something about this. I see climate change almost as the number one priority for the global community so I'm very personally motivated to influence this which leaks into my professional role and so what I can do in my role I will try to do.

In addition, one expert believes political factors, some functional justifications and cultural aspects are all working together to motivate people to be friends of the environment. He commented:

> *….discussions and cultural change without necessarily dropping into the politics and I don't see climate change as a political item. It's something which affects us all regardless of our view and our religion and where we come from and everything else; so I think it's entirely appropriate for the university to be taking much more of a lead addressing climate change and being champions of climate change response. USQ I think has a lot that it could do in this area but we also have areas of excellence with Rodgers Institute, of course, which deals with climate and some of the so for that gives USQ opportunities to be a regional leader; I mean to demonstrate a regional leadership role . We're not trying to change the world, but we certainly can influence the Darling Downs Toowoomba Southern Queensland area. I think we do that by example; in part, example of our own estate and our own operation and in parts the consultancy expertise, which we can work on together with our regional neighbour zone, Toowoomba Regional Council for example. Also, we can help other large organisations in the area.*

Institutions have an important role in encouraging staff to teach others to be friends of the environment. Through strategic work that provides an example of effective management by reducing their own emissions, they highlight the importance to protect and develop the environment—not only through teaching, but socially also. One expert states:

> *Universities are traditionally places for learning and they, I think, need to be [at] the front of some of the topical issues of the day such as managing energy issues.*

One manager also supports the above expert's point of view and states:

> *I think the university's original motivations for carbon reduction was all linked to the 2009 to 2013 strategic plan. Sustainability was a theme within that plan. So, if you want to have a look at the old strategic plan it's still available on the website. Therefore, the motivation for carbon reduction was directly aligned with that strategic plan and the goal of being carbon neutral by 2020. There was, in part I would say...the university had also wanted to be setting a strong example of being a very prominent corporative citizen within this community and much more broadly to be seen to be socially responsible in managing its environment. So there is that opportunity for the university to show its corporate responsibility and be seen to be a green university.*

Moreover, actual environmental information provides strong motivation for employees to improve their effort and commitment which, in turn, is reflected in economic, social and motivation factors. One expert divided motivation into three important sections and referred to them as follows:

> *The motivation for this is three fold. Firstly it's economic. Because energy prices are increasing and we're fools if we don't change our habits. Secondly, it's an environmental feeling that we have that we want to leave the earth*

> *better than how we got it, in a better state. And thirdly, there are social implications for our next generation; we have a strong obligation in us towards family; the thought of leaving the kids with a better earth.*

Finally, one expert said that the current stage is not in the motivation stage but there are incentives to work towards the improvement and upgrading of equipment to achieve higher efficiency and obtain a record of being seen as environmentally clean. He explained this as follows:

> *We are not really looking at that at this stage so it's more about, as we upgrade any plant and equipment, we make sure we are moving to the latest and greatest energy efficient type of stuff. Obviously if you're dealing from the start with a clean slate, it would be easier, but obviously when you've got a building that's 30 years old, it's not cheap or easy to suddenly turn around and throw everything.*

In the next section, using MACC and enhancing methodologies of MACC are clarified.

5.3.2 MACC

This section presents managers and experts' views of MACC. Section 5.3.8 demonstrates the findings about the definition and dimensions of a marginal abatement cost curve tool as a reduction strategy. Findings about the attributes of MACC are defined in section 5.3.9. Following this, sectoral assumptions about emissions' abatement are provided in section 5.3.10. Then, experts' perceptions about the determinants of assumptions for MACC methodology are presented in section 5.3.11. Finally, measurements for interventions to applying MACC are determined in section 5.3.12.

Using MACC

There are some corporations that use green strategies for energy savings and carbon reductions to disclose information to decrease their expenses and attract stakeholders, as well as to provide information to ecological authorities. Most interviewees have good ideas about using MACC and they have used the MACC approach in their organisation. For example:

> *Yes, we used MACC to determine which technologies we were going to implement as part of our substantive carbon reduction strategy. It was quite a simple approach, not sophisticated with our software tools so we used an Excel spread sheet to develop it.*

Generally the support for using MACC in organisations was because it is seen as an effective economic tool to build an environmental program. As one manager mentioned:

> *I do know about them because we did have a MACC done when we were doing the ecological transformation project so it showed us what was going to be the most economical for the university; what project was the most economical. Personally, I haven't got much experience or I haven't used a MACC curve,*

I've only been involved with that one construction, But I haven't myself used any.

MACC can be considered as a useful tool to express the flow of cash discount. At the same time, it is an important tool to help decision-makers to see the best trade-off options with respect to projects that reduce energy and environmental emissions. As one expert indicated:

I do know about marginal abatement cost curves. I'm doing one right now. It's a good tool to explain options but I also use it in conjunction with a normal graph that looks at discount cash flow. The idea of a MACC is a tool to help people decide on options; we have people who are very visual and we have people who work very well with numbers. I find that the MACC is a good one to use in conjunction with numbers. I think that MACCs are a good tool for visual people but shouldn't be the only tool in the way we communicate with people.

Identifying marginal abatement cost for emission reduction strategies

All interviewees confirmed that the MACC tool plays a significant role in achieving organisation objectives. They believe that MACC information can clarify for stakeholders the extent of their company's commitment to energy reduction strategies. MACC is placed as one of multiple strategies to reduce emissions and also works to determine the cost of options through a number of assigned projects to improve the environmental situations of an organisation—as one manager states:

Yes we have. Part of the carbon reduction strategy we developed and we zoomed on, at the time, I think it was for 2011 through to 2014. We were saying through this period we would like to do these things. One was a big solar PB farm, the other was tri- generational plant and the third item was a package of retrofit options to existing buildings such as glazing, insulation and so forth. I mean we modelled the cost and the benefit of all those things and the MACC we had, explored wind turbines, bio-maps, the in-ground heating and cooling stuff; we had solar water panels considered as well…

The actual implementation of strategies and methods that MACC requires minimises environmental impacts of the industries' operations. However, it is apparently difficult to effectively implement an environmental standard without strong backing from management hierarchy. MACC is used in foundation case studies. The case studies provide significant tools to manage the cost of reducing emissions. To obtain the best results from MACC, actual data and good methodology should be written based on specific options. MACC works better in dealing with energy. While there are restrictions in cases of diesel, it is an advantage in science in the field of energy to work with and determine the cost of options through a number of projects assigned to improving the environmental situation in an enterprise. In this regard, one respondent stated:

Yes, numerous. I just finished a big project with the meat industry. We had 5 case studies with 30 different treatments across 5 forms. There was a significant opportunity there. In a deviational department cost, I find most of them coming from CFI. What I'm also finding is the way the methodology *might be written might not be the best outcome for the former, so there hasn't been enough work within that option to determine what the best marginal abatement cost is. I've just done another one in Western Australia and it's one where I don't think the MACC works well and that's on a project on stroked diesel. So, if diesel is your only treatment, your marginal abatement is a flat box curve underneath because what happens is its 936, which is the rate, what changes is the area under the curve; so if you just work with diesel a MACC doesn't work well. If you put ULP in there and electricity, you will get changes in MACC, otherwise you will get a flat or a MACC below the line and it doesn't work well.*

Software used to generate MACC

Ellerman and Decaux (1998) found that it was appropriate to fit data to the MACC. If one desires to use MACC to estimate the prices of different CO_2 levels of mitigation, then there is a need to find some way of interpolating between simulations of price quantity points. MACC can be produced as graphs in Excel with its graphing option. All interviewees said they used the Excel program on the advice of some experts in order to save cost and achieve the most benefits. One manager states:

We didn't have any software especially for that so we used Excel. Basically, I created the tables in Excel, which took the data that we had from our ESD consultants about each of the options; so it modelled them, the cost and the benefit. We used that against the university's 2009 base line and did a carbon emission inventory in 2009, which we use as our base line for tracking our performance.

One expert used Excel and was able to produce a MACC curve. The original one had been produced by consultants and he replicated theirs:

I used Microsoft Excel to do it and I wrote the spread sheets myself.

Sectoral assumptions

Energy models, however, often provide the possibility to show the sector's distribution of emission reductions. The order derived from this sector's literature is based mainly at the expense of overall cost savings through the wide adoption of new technology used. On the assumption that all companies adopt new technology, the authors calculate the total cost of the industry before and after the adoption of the new technology, and then compare the differences.

We can say that assumptions are built on the foundations of deep research. Governments and sectors are keen to adopt these assumptions in order to help companies carry out emission reductions. One justification for assumption is the conclusion of Ellerman and Decaux (1998) that MACCs are in fact strong with respect to environmental policy. Often assumptions come under political or developmental objectives for environmental regions, sectors and institutions. One manager states,

> *I don't know if I'd use the word assumption, but the environment, I think the state government and the federal government, they are very political environments, and university funding which is quite straight forward and is related to the number of students who are involved, you know, it's that simple. And then there is a package of other bits which sit around the edges. Some of it relates to infrastructure development and those areas tend to be more volatile and more exposed to the political changes—and some of the influences for us was we couldn't rely on getting federal or state funding to assist us with some of the solutions,…*

Because some sectors are non-binding mandatory reporting, they are focused on environmental behavioural changes within their organisations. Thus put carbon footprint and can reference their commitments made in the framework of government considerations, especially if the government has funded some projects related to energy conservation and emission reduction. This view is illustrated by the next quote from one manager:

> *Because we are not a high end footprint and a high end polluter and our footprint is not overly high, we don't trigger a lot of the mandatory style reporting that other larger universities in our sector do and with that mandatory reporting, the larger the footprint, the larger the need to trigger behavioural change and organisational change. Our actions have been motivated more on us wanting to make change within the organisation so that we can prove our footprint rather than being forced. ... What did happen in the last couple of years was the university did start reporting at a state level under the Queensland Smart Energy Savings Program, which was an initiative of the former state government; so the university established its baseline under that program and then set about formalising some processes required under state legislation.*

Institutions have specific plans for energy saving through some of the programs. They are also trying to work some sort of balance between the available initiatives and their potential to obtain financial benefits from investments in the environmental field.

The university did a level two energy savings program and then also developed a smart energy savings action plan which were requirements under that program; however, that program has been disbanded by the current government. We are still forging ahead and balancing those initiatives. The university can manage from a financial perspective, and looking at those initiatives on case by case basis, to make sure that there's a good financial return and also a good environmental benefit for producing those projects.

MACCs are based on assumptions, initiatives and projects available, and the development of MACCs is also based on the discounted cash flows of the business case. In light of this, one of the experts has expressed his view as follows:

Assumptions occur all the way through the MACC that we develop. One of the things that you're doing is, you are always using a discounted cash flow from the business case, so that you are going to have to make assumptions across the board. So if I'm using a farm in Western Australia and I'm comparing properties in their diesel use, it might be a factory, it doesn't matter, I have to assume that I'm comparing the two, that both have the same driver under the same conditions, and we would expect those sorts of savings. I find universities very different from an education perspective because I've done some work for UQ and I have done some work for USQ, and I find UQ will leap some bounds ahead of what's happening here in USQ. Therefore, the assumption is UQ is willing to capitalise on the energy savings program. Why they have to do that is in fact because they started so they have to do something about it as part of EO; but USQ don't have to.

Assumptions for MACC methodology

MACCs clearly show the extent to which the different combinations of measures can be used. This transparency benefits largely by the extraction of reduction strategies. However, when applying MACCs, it should be noted that the costs are only ball park estimates and have no secondary impacts included (Beaumont, N. J. & Tinch, R. 2004). Significant assumptions have also been developed, but these are transparent and well-justified, and thus must not largely affect the validity of the results. This has been inferred by the following statement from one of the managers:

I think the major one and the one which had truly the most influence was the cost of carbon and we assumed twenty-three dollars per tonne. The rest of the data within MACC in terms of what it will actually cost to install this equipment and to implement these solutions, we challenged on a number of occasions. From the estimates that were given to us, we had independently developed prices. From estimates by consultants we had [to] internally review things, to see whether we believe they were realistic. In some cases, we got alternative prices; so the data which we put into the MACC about the cost to implement the solutions to us is pretty robust.

The presuppositions inevitably play a role in estimating costs and how consumers and companies can see risks and differences in the quality of sustainable technologies. Empirical study provides valuable information for policy-makers in assessing the likely response to a set of policies. This, in turn, assists in assessing the costs of carbon. One expert states:

I think in any discussion around MACCs now, the big question is what the price of carbon will be. If you look at the price of carbon in Europe it's very different. No, and I think having a high price for carbon is one way to drive change and to make the renewable technology more economically viable. To some extent, I was really comfortable with the twenty-three dollars, and of course, it was the figure which the government was going to set and has set. However, I think if we are going to start going down to six or seven dollars a tonne then what changes are we going to see? Almost none, it isn't a threshold which encourages expenditure on sustainable technologies.

Another expert confirmed that he realised the assumption of prices of carbon is very important for driving and developing MACC:

The only assumption, of which I'm aware, was the pricing of the carbon tax and carbon pricing mechanism. They made the assumption at the time because it was done pre-carbon that the pricing would be simply $3 a tonne, that's the only assumption that I'm aware of that, was made in the development of the MACC.

Presenting several assumptions works to produce MACC relative to specific business. These assumptions should be accurate in reflecting real abatement for particular businesses. In the words of one expert:

In producing a MACC, you've got to produce a baseline and a cue that will give you the marginal abatement difference. So when I produce a MACC for a particular business, I'm going to have to make numerous assumptions around how those businesses operate and to ensure how I compare the case with the base to make sure that there's no influence and I will tell you why. I'm having this trouble with the project in Western Australia at the moment. I'm building a MACC for people to put their own data into but I have to assume they are making measurements at their end that are as accurate as the measurements we are making at our end. A plus or minus of 10% in their measurements can have a significant effect on the MACC outcomes for the other end. So if they are not measuring the way they should be measuring, we have got a problem downstream.

Measurement results of intervention identified using MACC

All interviewees worked and carried out the measurements from the interventions only for the purpose of comparisons. Sometimes these measurements did not have sufficient precision or clarity. However, the measurements need to get to real/actual data or improve the ability to create useful data. These attempts to access more sound data contribute to producing MACCs results relating to developmental and environmental work. Three managers stated:

Correct, so it is a calculated saving rather than a measured saving, and I think that's the difference. We would try to improve the metering, so we can get actual saving, but the other part of that, of course, is to give information back *to the users of that space and that equipment, and that's something we have yet to do.*

No, not using a MACC. Where we are able to, we do measure the interventions but as I just said we only recently have had metering in place for that. Previously we've had to work it or derive it from the equipment that we have installed for the operation now—that sort of thing, so it's not really a clean indicator.

No, the university is still in a phase of rolling out comprehensive metering, so where we put an initiative into an area where we already have sub-metering, we were able to use that data to do a direct comparison of pre- and post-interventions. However, not every building is sub-metered to enable us to have that ability to look more closely at the data.

5.3.3 Supporting and developing MACC

Benefits and barriers encountered using MACCs

MACC is an important and useful tool in the process of supply for decision-makers to understand the possible options for the reduction of emissions and cost savings. MACCs also provide a way to analyse data and make comparisons. As one expert stated:

> *I think the MACC is a wonderful visual tool when you're presenting to a group of decision-makers or stakeholders. The MACC is a very clean and understandable way of saying this particular measure gives this much of carbon reduction and at this cost and they can immediately understand that. So I think it's a wonderful communication tool with a good balance of the actual hard data and analysis when represented visually. I think the MACC is great for that.*

It is important to know how to deal with the MACC as a working tool technically. Execution of the work is required by the organisation internally, as a requirement by sector levels, and for the purposes of the government. Some staff are familiar with the importance of MACC, but they require greater training and experience. In this regard, one manager states:

> *Personally I don't know enough. I haven't worked on developing my own MACC curves, so I probably need to work with some people specialists in the field in the accounting area about developing MACCs. My experience has been only with working with consultants who have developed the MACCs from the work that we have done. The barrier has been my lack of knowledge about how to achieve a MACC curve myself. The benefits are definitely quite high because we have used that curve on a number of occasions, in reports to show very clearly a direct comparison of implementation of particular initiatives, how they compare, and the benefit from a cost analysis point of view.*

Mostly, MACC tools have a variety of benefits, but represent a cost to the organisation. MACCs need alternatives and these require change in equipment. These changes are the kind of barriers that people have difficulty understanding. As one expert said:

One of the things that I found that is a problem with the MACC is, in some ways it's counter intuitive. It starts low and then goes high. So the problem I see in that is, you've got to spend a lot of time explaining to people about the savings. I find that people are more interested in the dollar savings. So, if I get to a straight *discount cash flow model, a grower can see that they are going to save that amount of money from doing those different sorts of activities. I've still got a MACC there but unfortunately the MACC looks like that because it's always at that 356 solar mark. So that's one of the barriers, people find it difficult to understand.*

Support from top management

Environmental action needs support morally and financially from senior management and/or sectors and/or the government. This support is for adopting strategies and encouraging initiatives to provide financial support for programs to reduce emissions and preserve the environment. These operations take a long time for completion. As indicated here, one expert states:

In the period 2009 to 2011, it was very well supported because it was an explicit target in the strategic plan. We had a new vice chancellor in 2012 and we have different organisational priorities now, so the university is putting a lot of its effort now into developing its research capability. It had to do some of that because of the change in the federal environment and the way the university funding is going, so we have to do more research. The university only has a certain amount of money and so some of the things we have been doing, have been put on hold. They are suspended till we get further through restructuring research, and all the other stuff; then we will come back and talk again about where we pick up the carbon reduction strategy.

Moreover, one manager supports the above viewpoint with the following statement:

We have received a lot of support from the senior executive to date around implementation of energy saving initiatives coming in under [the] carbon reduction project…

The other aspect is the change to goals, strategies and positions of government which means some environmental policies cannot proceed. This has a significant impact on the failure to develop and/or complete some programs that could result in a considerable reduction in pollution and provide savings in energy consumption. However, the advantage of some tools such as MACC is that they can still keep providing research and innovation to continue implementing real projects for the reduction of pollution and energy; therefore, obtaining and continuing the benefits of reductions. One manager states:

...however, there has been in recent times, as I touched on earlier, a change of focus with the new strategic plan. We are in a situation at the moment of reassessing what that means; given the carbon reduction strategy is linked to the new strategic goal of managing an economic and an environmental footprint responsibly. These implementations are linked to what we need to get a broader understanding from senior executive as to how they see that strategy being implemented and/or whether we need to be putting it to the

business case board to fund the initiatives under the carbon reduction strategy. Previously we had money ear-marked within the campus capital asset management plan with review of available funds. However, the stakeholders that we had around funding some of those initiatives were removed so therefore we are operating on [a] reduction [in] funds; therefore, our ability to readily fund the larger carbon reduction projects has been removed. We are seeing if those projects can be worked collaboratively with research groups. We could take the basic project and work with researchers and PhD students to tweak the projects to make them into learning and teaching experiences and something that can attract funding grants. The use of MACC to guide us, I suppose, was when the carbon reduction strategy was presented as part of the overall report that clearly outlined the strategies that were definitely going to benefit the university in terms of its implementation. The MACC curve made it very easy for members to look at the projects and see the definite benefits of implementation around the cost. Any projects that were going to cost the university more than the $23 a tonne to abate the carbon were deemed not feasible and would be revisited at another point in time to see if things have changed.

MACC is regarded as a useful tool, but one interviewee has some problems, such as in the case of using diesel. Such cases relate to factors associated with financing, rate of return, discounts, and risks. In this regard, one expert pointed out:

For those people who get it, MACCs are a good way to explain the benefits. That's the problem with the diesel one, but if I'm looking along here (the negative area of the MACC graph), you can look at the area under the graph and you're going to have more money over harvesting. The next one is probably fertilising and then we are looking at our trucks being a major savings options. The other benefit is actually going through the process and a lot of people don't do it. We do a lot of our work in agriculture; I find a lot of people don't spent the time doing the discounted cash flows. One of the other things is that we are going to put in a risk premium. We are trying to put it also in different projects, like you might have a standard ROY of 7% that you are using in your MACC but we are also going to put on a risk rate depending on the project because not all the projects have the same risk. I think it's worthy of a paper to show how do you determine risk rates in marginal abatements by doing discounted cash flows from one project to another because some projects are more risky than others and should attract higher risk.

Optimal strategy for organisation to maintain sustainability

MACC can be optimal for providing many environmental options. One particular MACC may not be suitable for all companies. Differing factors must be taken into account for additions such as consideration of behavioural issues. Innovation in energy technologies gives a distinctive shape for important choices, which contributes to investment for improving the environmental situation. In this regard, one expert stated:

I think there are typical things which organisations should look at or they can do. There isn't going to be a single answer for everybody, but I think there *will be categories of things which will be common for everybody; you've got a couple of them here. Changing behaviour is a really big one because there are two approaches to use. One is to put the best infrastructure in place and that could be renewable energy technology; could be a solar farm; could be tri gen; could be co gen; could be a number of things. Those are the big ticket items which the corporate body enterprise need to really engage with, because everybody can see the organisation is serious and the organisation has made an investment. Therefore, this is important. This makes it easier to change behaviour in all of the staff and students and members of the organisation. I think you could start at either end and we certainly tried to do that.*

In this context, one of the directors supports the importance of the behavioural aspect, especially long term. Particular examples include some of the changes and interventions that contribute to the control and monitoring of the workplace environment for energy savings and reduction in emissions. The director states that:

I think that an organisation needs a balance between two, I think that behavioural change takes quite a long period of time to initiate. In an organisation such as the university which is quite transparent particularly with the student body, it's more difficult to maintain a change in behaviour. The university's focus has been more so around changing technology. Things we can do that remove or take the focus off behavioural change and enable the university to have a greater control over its ability to manage its footprint more responsibly. For example, the university has been working towards changing lighting over in key areas; they have put LED lighting in some newly refurbished spaces such as hallways and other things to reduce costs. From a maintenance point of view and to reduce the costs in terms of the life of equipment, we are also implementing a power management change in the way in which the university operates our ICT equipment, which is a new project that is collaborative between the environmental office and ICT. So, we look at what will allow us to have a strong level of control in reducing our overall energy costs. Other things we are looking to do is introducing occupancy senses, managing our set points through our BMS system, our BMS management system. Where we can effectively manage the overall footprint of the university and take that control away from the users and set it to a manageable level, we will do that by controlling the lighting and the air in the lecture theatres, readjusting the set points by putting occupancy senses in the power management, all of those things. When we have implemented all of those things, then we can start to focus on changing behaviour by educating the staff and the students, particularly the staff that have the greatest influence around being able to control lighting in areas and controlling air conditioning, the things where we haven't got control and that sort of thing. It's about education but where possible we are trying to remotely manage behaviour.

In an attempt to preserve the environment, training has provided a positive impact in strengthening the foundations of institutions. Training in the environmental field contributes to creating a kind of job stability; and helps control and censorship. Training with job stability can encourage staff to carry out the initiatives and facilitate the involvement of employees and their integration into the culture of beneficial environmental aspirations of the institution and the community. Another interviewee supported this view with the following statement:

We did things like creating the sustainability inline training module for new staff. We've changed position descriptions that require everybody to sustain stability in their day to day jobs. We've got the Lily Pad Environmental Office; we've created the environmental officer position; we've done a number of things around staff and students engagement to get the message out there and raise the profile. We've done a number of, what I'd call, age technology solutions with the metering, and the building management system, and the energy orbits, and the lighting and so on, but we haven't done the big stuff, the big infrastructure changes just yet. So I think if you look at all of these things realistically, I would say that the best solution that you come up is with a balanced support folio of measures that works for your organisation at this point in time. Some organisations all have an environmental culture where it'll be easier to engage staff than another organisation [that] has an entirely different culture or structure and it's very difficult to engage staff. Organisation A may be very wealthy in terms of its capital reserves and it can easily fund the big infrastructure; organisation B may not.

On the other hand, there are many differences of opinion about the importance of preserving the environment. However, MACCs are seen as a pioneer in the ability to help managers choose between alternatives and environmental decision-making. In this regard, one of the experts indicated that:

It varies. Across the board, I have some clients who just embrace it like there is no tomorrow, they just believe in it. Then there are others who are far too busy trying to stay afloat; they don't worry about saving some energy. They want to save some energy but there are too many other things impacting on their time. Carbon reduction strategies in the community have gone off the boil, I believe. You just have to have a look at it. It has a lot to do with government policy. For instance in Qld we've just had a situation where this government doesn't believe in carbon issues, so no money has been put into that area from a government perspective. All of the major firms are tired of the carbon theme and sustainability in general seems to be on the nose. Uses of MACCs in decision-making—most of them like it—but I think there is a level of sophistication in their ability to understand. It flows in the people I work with and I tend to choose my clients.

MACCs usefulness in identifying least cost and best reduction strategies

Most of those interviewed stated that MACCs are useful, provide clear lines and combine many strategies. MACCs can be most effective if effort and accuracy are present in their implementation, because applying MACCs depends on real information. MACC's tools that combine financial support and balance environmentally will be valid for changing circumstances. MACCs are also able to deal with behavioural changes in people and are more capable than other applications of this type in achieving savings in energy and costs. As one expert states:

For me philosophically, it's the balance between financial, environmental and social drivers. How sustainable you are may change with financial, environmental or social conditions, mostly financial. For change, people's behaviour is looking at options so they can save money. In the client I'm looking at—but again one of the clients for instance—if it doesn't reach the

18% ROY then they are just not going to take it on and it's a 4.5 million dollar project. That will leave them not actually having a multi-million dollar electricity bill but it has got to hit the ROY. In changing technology, I've worked with clients for a number of government funding opportunities. When government funding is involved, they are more likely to do it because it reduces the risk within the project.

Proposition two (**P2**) posits that *"There are no shortcomings in current MACC methodology*". Current MACC methodology accounts for: 1) emission reductions and energy saving; 2) identifying and using marginal abatement cost curve—useful and important for all organisations; 3) and choosing an appropriate accounting policy such as MACC played an important role interacting between and setting levels for energy saving and abatement of emissions in the organisation. However, new information from the research of this study created a need to expand the current MACC methodology. The findings from experts and managers indicated many shortcomings involving current MACC. Therefore, proposition two is **not supported.**

5.4 Chapter summary

This chapter analyses the energy use by providing the trend of energy consumption over the period of study. In addition, comparisons between the years have been made to explain what happened in this period of time. Then abatement data was provided from different sources and a theoretical MACC has been created for this study from different options that are available for this application. The costs of implementing these options were illustrated and the benefit from each option has been highlighted.

The previous literature and reports are considered the most important document among theoretical MACCs. The results of this part of the study show current importance of historical data contributed to providing theoretical MACC. The results in this chapter also show that MACC is exhibiting a greater concern in improving corporate environmental performance by increasing information in reports.

To conclude, this chapter reveals that energy users have made more effort in saving energy. Trends in USQ energy use and comparison for four years have been established. The trend of emissions at USQ has been presented and the comparison has been provided. Emissions of GHG are expected to decrease under different assumptions—and also orientation towards environment and sustainable development values. Using theoretical MACC provided sound foundations to understand which options can be implemented for energy savings and abatement emissions. The chapter has also highlighted that the potential for emission reductions are considerable and at less cost. The chapter has presented deeper insights and findings into the perceptions, opinions and attitudes of managers and experts about the importance of the development of methodologies for MACC. The interviews in this research with managers and experts reveal their insights for developing MACC. The chapter reports the findings of development into MACCs' approaches. Specifically, the results in this chapter have clarified the extent of organisational energy use and emissions reduction. Moreover, the results indicate that there are important motivations for CO_2 reduction. The results obtained used MACC tools. Finally, many insights about the support given to the development of methodologies for MACC are provided. Chapter 6 provides an analysis of the findings relating to behavioural aspects.

CHAPTER 6: ANALYSIS FINDINGS - BEHAVIOURAL ASPECTS

6.1 Introduction

Chapter 5 provided the MACC data results through descriptive data relating to USQ energy use and emissions; it also presented the quantitative data from a particular project for this study. This chapter reports results from the behavioural aspects analysis and the content analysis that relate to the development of methodologies. These details describe the data from the study's fieldwork gathered through surveys of residents of Steele Rudd College.

6.2 Assessment of behavioural changes at first rotation

Assessment of the baseline (first rotation) was divided into four sections which were the overall assessment for the behavioural changes (see figure 6.1); the attitudes towards energy conservation; the answers to multiple choice questions that address student perceptions and behaviour with respect to electricity use; and the knowledge and GHG effect on climate change as follows:

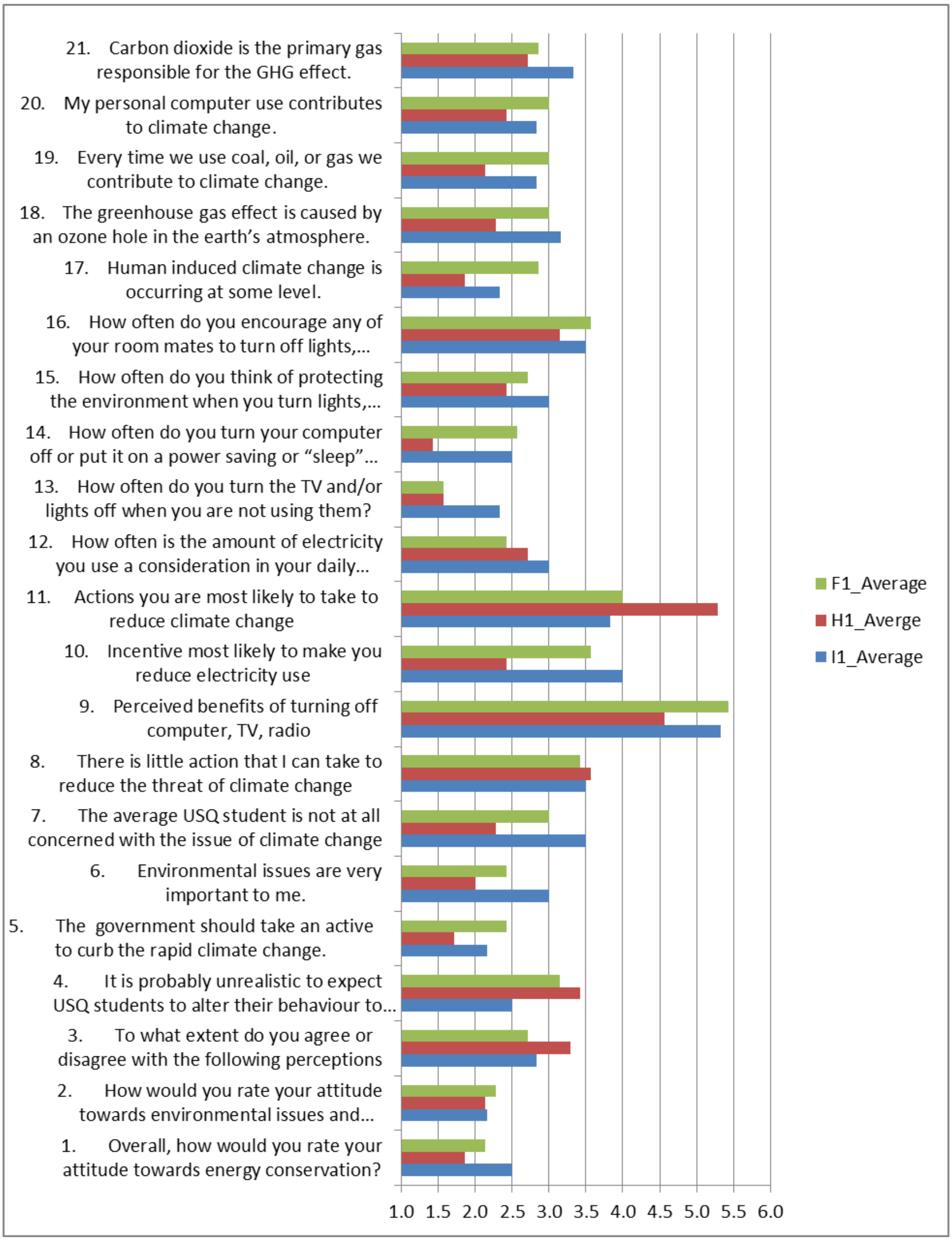

Figure 6.1 Overall assessment of behavioural changes baseline first rotation

6.2.1 Attitudes towards energy conservation at first rotation

In the first rotation and before interventions, assessment of the three groups for attitude towards energy conservation had the highest scores for question 8 (Figure 6.2). The responses indicate the three groups strongly agree that there is little action that can be taken to reduce the threat of climate change. These represented a response rate of 57% from group I and 57% from group H; whereas group F represented a response rate of 42%. However, these percentages might also be the result of these responses shifting some of the responsibility to respond to climate change from themselves to the government. In comparison, the lowest scores from the three groups' surveys were for question 5. This indicated that the respondents were not worried about the issue of climate change, even though the government emphasised this phenomenon. These scores represented a response rate of 71% for group I, 42% for group and 57% for group F.

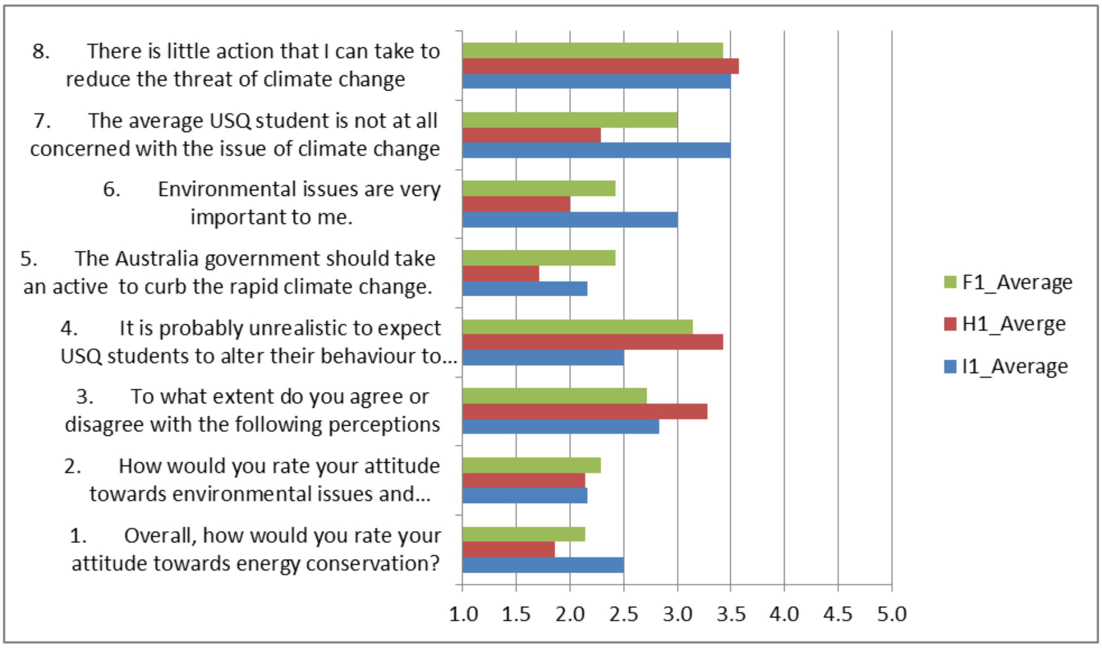

Figure 6.2 Attitude on energy use and climate change at baseline first rotation

6.2.2 Multiple choice questions addressing student perceptions at first rotation

In the first rotation and before interventions, several interesting results were obtained by the empirical assessment. Table 6.1 summarises empirical results of multiple choice questions with regard to energy users and what they prefer overall.

Table 6.1 Results of multiple choice questions at baseline first rotation

Topic	Options	Top choices
Perceived benefits of turning off computer, TV, or radio	Reducing noise Reducing the threat of climate change Making TV/computer last longer Reducing air pollution Reducing the cost of room and board for future students	**Reducing the cost of room and board for future students** **Saving USQ money**

Topic	Options	Top choices
	Saving USQ money Protecting the ozone layer Protecting the environment	
Incentive most likely to make you reduce electricity use	$20 reduction in bursar's bill Knowing you are doing good for the environment Having to pay for your electricity use A barbecue for your dorm Recognition from dorm mates Knowing it's good for your appliances Knowing that you are not being wasteful	**A barbecue for your dorm** **Knowing you are doing good for the environment**
Actions you are most likely to take to reduce the impact of climate change	Walking instead of driving Switching to fluorescent bulbs Voting for legislators that support pollution controls Asking for more energy efficient policies at USQ Recycling Turning off your computer at night and when not in use Flying less Eating less red meat Buying a more fuel efficient vehicle Enabling power management function on computer	**Recycling** **Turning off your computer at night and when not in use**

Group I: Their top choices from multiple options relate to perceived benefits from turning off computers, TVs and radios to reduce the threat of climate change and to protect the environment. Group H: Their top choices are saving USQ money and reducing the cost of room and board for future students and is similar to group F regarding saving USQ money and protecting the environment—which is also similar to Group I.

Regarding the incentives most likely to motivate respondents to reduce electricity use, group I's top choices are a barbecue for their dorm and $20 reduction in bursar's bills. Group H's top choices are: knowing you are doing well for the environment and $20 reduction in bursar's bills. On the other hand group F's top choices are: a barbecue for the dorm and knowing you are doing well for the environment.

Actions that are most likely to reduce the impact of climate change: Group I's top choices are recycling and turning off computers at night and when not in use; which is the same as Group H; whereas group F's top choices are recycling and walking instead of driving.

6.2.3 Behavioural aspects with respect to electricity use, knowledge and GHG effect on climate change at first rotation

In the first rotation and before interventions, the results of the survey indicated that the three groups of respondents regularly practised electricity conservation with their lighting and appliances, but were less likely to practise the same behaviour with their computers (Figure 6.3). Interview responses suggest that knowledge of the differences in energy usage between appliances and other technological equipment may be responsible for this difference in energy conservation behaviours (Figure 6.4). Group I's highest score was for *How often do you encourage any of your room mates to turn off lights, computers, or appliances to save energy*? (Q16). These responses were neutral and represent 30%. This was similar to Group F, which represents 28%. In contrast, the lowest choice is that human induced climate change is occurring at some level. Interviewees of group F also stated they were under the impression that leaving their computers on was better for their computer components.

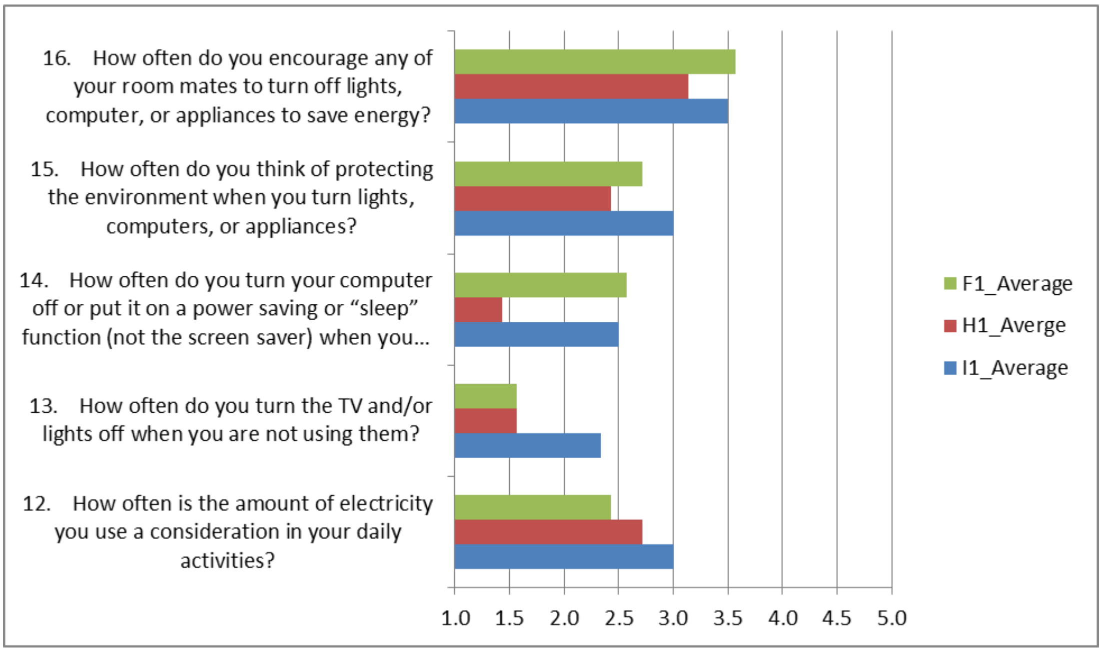

Figure 6.3 User acceptances of energy abatement initiatives

Although research has found that knowledge is not the only component of a decision to engage in pro-environmental behaviour, it does play a significant role. Public misunderstanding of an issue can complicate environmental problems and create significant barriers to education and behavioural change (Oleckno 1995). Respondents have different responses—although both groups F and I indicated a strong belief that climate change is occurring (Figure 6.4).

6.3 Assessment of behavioural changes at second rotation

In the second rotation, assessment of the first rotation was divided into three sections which were attitude towards energy conservation, multiple choice questions addressing student perceptions and behaviour with respect to electricity use and knowledge, and GHG effect on climate change.

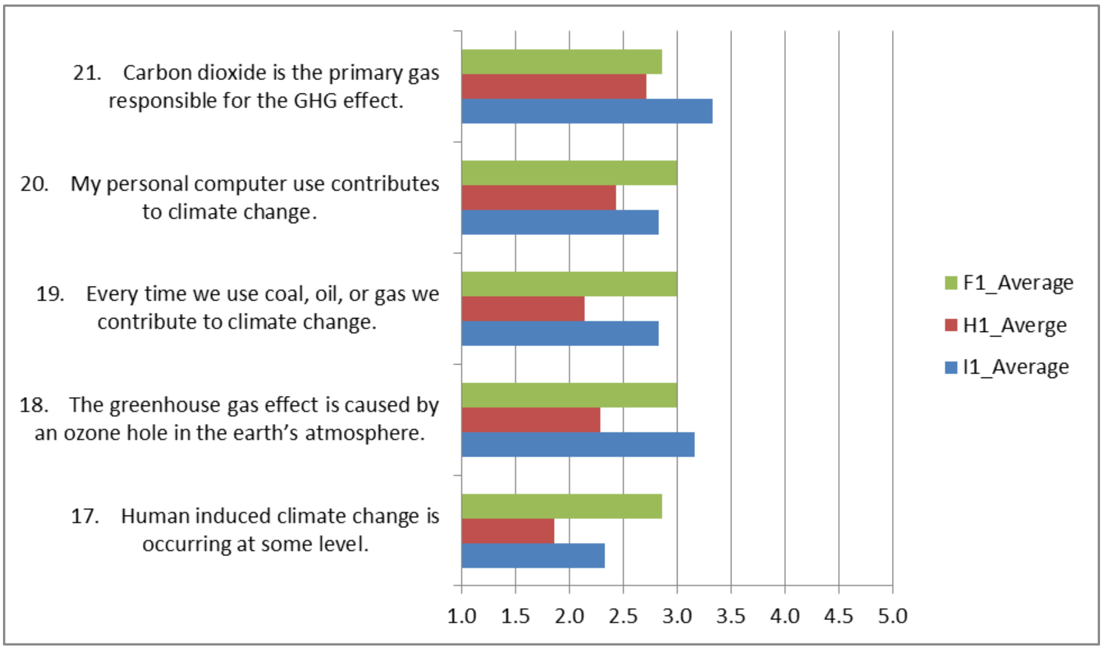

Figure 6.4 Behavioural related knowledge and greenhouse effect on climate change at baseline first rotation

6.3.1 Attitudes towards energy conservation at second rotation

Assessments in the second stage showed the attitude of different groups. The highest responses from Group F related to Q3 (57%): Currently, society is acting sufficiently to conserve energy to ensure that future generations are not affected. These responses indicate agreement with this statement. The highest responses of Group I were for Q8: There is little action that the researcher can take to reduce the threat of climate change and the responses are in agreement with this opinion. The highest responses of Group H were for Q7: The average USQ student is not at all concerned with the issue of climate change .They neither agree nor disagree, as in shown Figure 5.6.

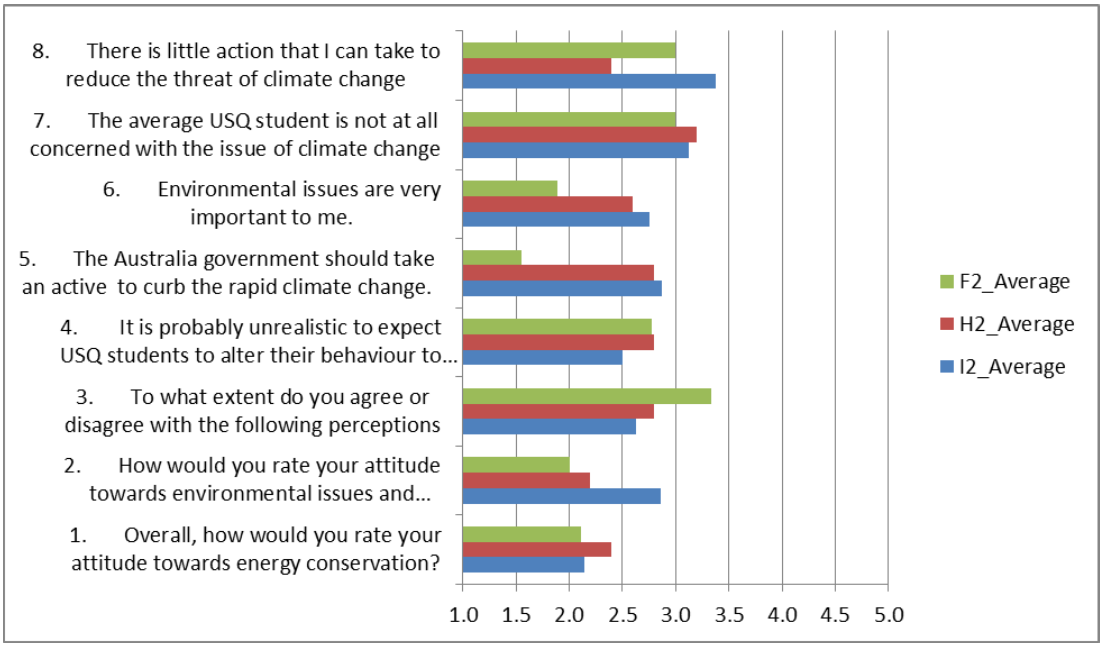

Figure 6.5 Attitude on energy use and climate change at second rotation

6.3.2 Multiple choice questions addressing student perceptions at first rotation

In the second rotation after first interventions, several interesting results were obtained from the empirical assessments. Table 6.2 summarises empirical results of multiple choice questions with regard to energy users. What respondents preferred overall was reducing noise and reducing the cost of room and board for future students.

Table 6.2 Results of multiple choice questions at second rotation

Topic	options	Top choices
Perceived benefits of turning off computer, TV, or radio	Reducing noise Reducing the threat of climate change Making TV/computer last longer Reducing air pollution Reducing the cost of room and board for future students Saving USQ money Protecting the ozone layer Protecting the environment	**Reducing noise** **Reducing the cost of room and board for future students**
Incentive most likely to make you reduce electricity use	$20 reduction in bursar's bill Knowing you are doing good for the environment Having to pay for your electricity use A barbecue for your dorm Recognition from dorm mates Knowing it's good for your appliances Knowing that you are not being wasteful	**$20 reduction in bursar's bill** **Knowing you are doing good for the environment**
Actions you are most likely to take to reduce the impact of climate change	Walking instead of driving Switching to fluorescent bulbs Voting for legislators that support pollution controls Asking for more energy efficient policies at USQ Recycling Turning off your computer at night and when not in use Flying less Eating less red meat Buying a more fuel efficient vehicle Enabling power management function on computer	**Recycling** **Walking instead of driving**

The top choices from multiple options relate to perceived benefits from turning off computers, TVs and radios to reduce the threat of climate change. These top choices related to reducing the cost of room and board for future students. Group H: Their top choices were making TV/computer last longer to reduce the cost of room and board for future students and is similar to group F, reducing the cost of room and board for future students and reducing noise—which is also similar to Group I.

Regarding the incentives most likely to motivate respondents to reduce electricity use, Group I's top choices are: $20 reduction in bursar's bills and recognition from dorm mates; which is the same as Group H's top choices, $20 reduction in bursar's bills and recognition from dorm mates. On the other hand, Group F's top choices were the same as Groups I and H but included: knowing you are doing well for the environment.

6.3.3 Behavioural aspects with respect to electricity use, knowledge and GHG effect on climate change second rotation

In the second rotation and after some interventions, the results of the survey revealed differences, as shown in Figure 6.3. Interview responses suggest that knowledge of the differences in energy usage between appliances and other technological equipment may be responsible for this difference in energy conservation behaviours. Group I believes that primary gas rates highest in releasing carbon dioxide and is responsible for the GHG effect that was surveyed in Q21. Group I registered the lowest choice for *how often do you encourage any of your room mates to turn off lights, computer, or appliances to save energy* in Q16 and that *human induced climate change is occurring at some level.*

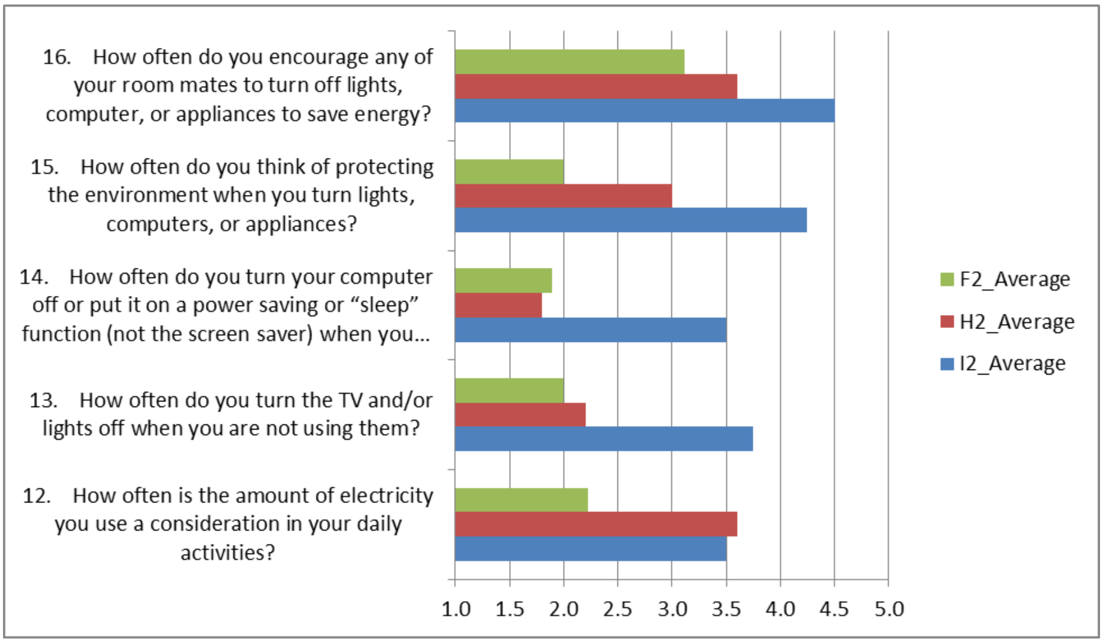

Figure 6.6 Users' acceptance of energy abatement initiatives

Group F's highest responses were for Q16: *how often do you encourage any of your room mates to turn off lights, computers, or appliances to save energy*. Group F's lowest choice is Q14 for *how often do you turn your computer off or put it on a power saving or "sleep" function (not the screen saver) when you are not using i*t.

Group H's highest responses were for Q12 and Q16 respectively: *how often is the amount of electricity you use a consideration in your daily activities*?' and *how often do you encourage any of your room mates to turn off lights, computer, or appliances to save energ*y. Group H's lowest choice was the same as Group F which is Q14: *how often do you turn your computer off or put it on a power saving or "sleep" function (not the screen saver) when you are not using it*.

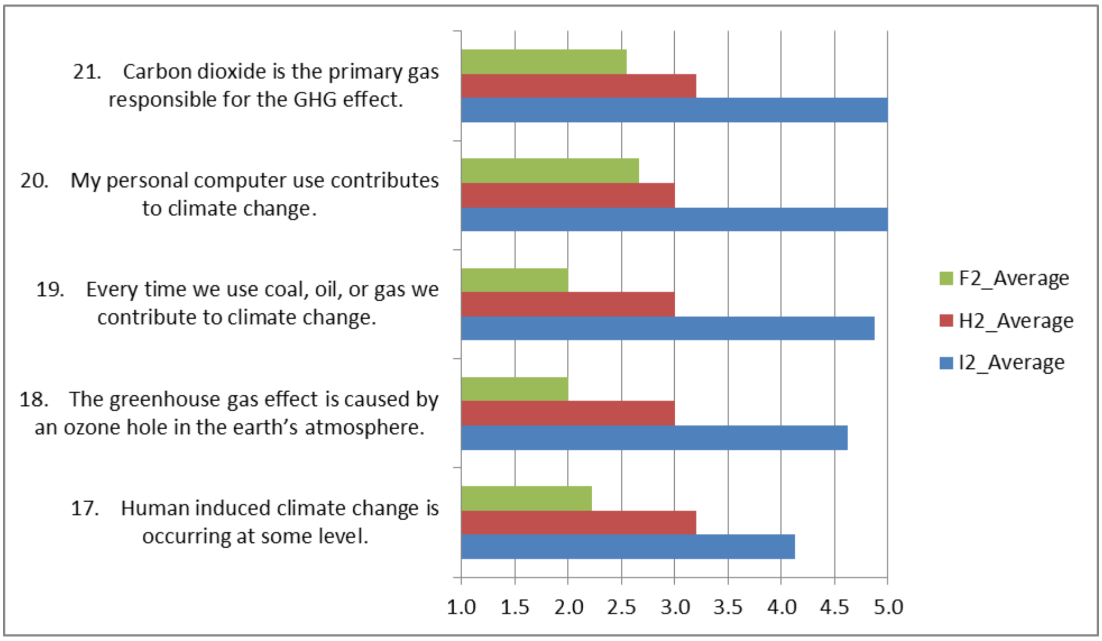

Figure 6.7 Behavioural related knowledge and greenhouse effect on climate change at second rotation

6.4 Assessment of behavioural changes at third rotation

Assessments from the third rotation were divided into three sections which were attitude towards energy conservation, multiple choice questions addressing student perceptions and behaviour with respect to electricity use and knowledge, and GHG effect on climate change.

6.4.1 Attitudes towards energy conservation at third rotation

Assessments in the third stage showed the attitude of different groups. The highest responses of Group F were for Q8: *There is little action that I can take to reduce the threat of climate change.* These responses neither agree nor disagree and represent 50% of responses. The highest responses of Group I were for Q1: *Overall, how would you rate your attitude towards energy conservation?* The responses were neutral and represent 63%. The highest responses of Group H were for Q3: *Currently, we as a society are acting sufficiently to conserve energy so as to make sure that our future generations are not affected.* They strongly agreed and represent 44% of responses, as shown in Figure 6.8.

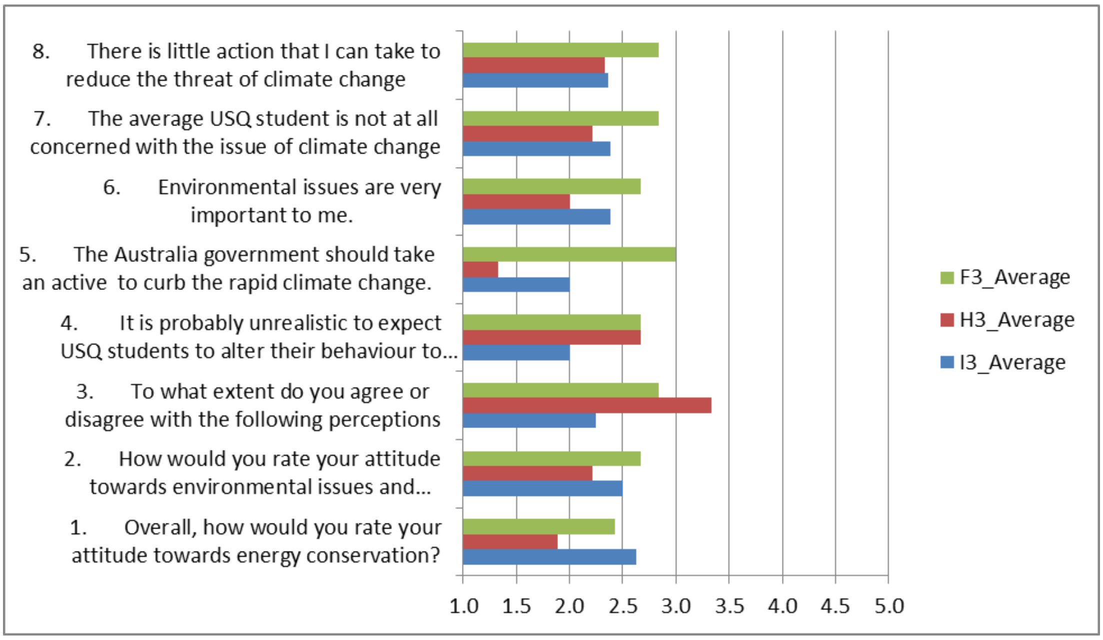

Figure 6.8 Attitude on energy use and climate change at third rotation

6.4.2 Multiple choice questions addressing students' perceptions at the third rotation

In the third rotation after first interventions, several interesting results were obtained by the empirical assessments. Table 6.3 summarises empirical results of multiple choice questions with regard to energy users. What they preferred overall was recycling and gaining a $20 reduction in the bursar's bill.

Table 6.3 Results of multiple choice questions at third rotation

Topic	Options	Top choices
Perceived benefits of turning off computer, TV, or radio	Reducing noise Reducing the threat of climate change Making TV/computer last longer Reducing air pollution Reducing the cost of room and board for future students Saving USQ money Protecting the ozone layer Protecting the environment	**Making TV/computer last longer** **Reducing the threat of climate change**
Incentive most likely to make you reduce electricity use	$20 reduction in bursar's bill Knowing you are doing good for the environment Having to pay for your electricity use A barbecue for your dorm Recognition from dorm mates Knowing it's good for your appliances Knowing that you are not being wasteful	**$20 reduction in bursar's bill** **Incentive most likely to make you reduce**

Topic	Options	Top choices
	Incentive most likely to make you reduce	
Actions you are most likely to take to reduce the impact of climate change	Walking instead of driving Switching to fluorescent bulbs Voting for legislators that support pollution controls Asking for more energy efficient policies at USQ Recycling Turning off your computer at night and when not in use Flying less Eating less red meat Buying a more fuel efficient vehicle Enabling power management function on computer	**Recycling** **Turning off your computer at night and when not in use**

The top choices from multiple options relate to perceived benefits from recycling and gaining a $20 reduction in bursar's bill. These top choices include *Making TV/computer last*. Group H: Their top choices of recycling and acquiring a $20 reduction in bursar's bill; and are similar to both group I and Group F. Another of Group F's top choices is *reducing the threat of climate change.*

6.4.3 Behavioural aspects with respect to electricity use, knowledge and GHG effect on climate change third rotation

In the third rotation and after some interventions, the results of the survey revealed differences, as shown in Figure 6.9. Interview responses suggest that knowledge of the differences in energy usage between appliances and other technological equipment may be responsible for this difference in energy conservation behaviours.

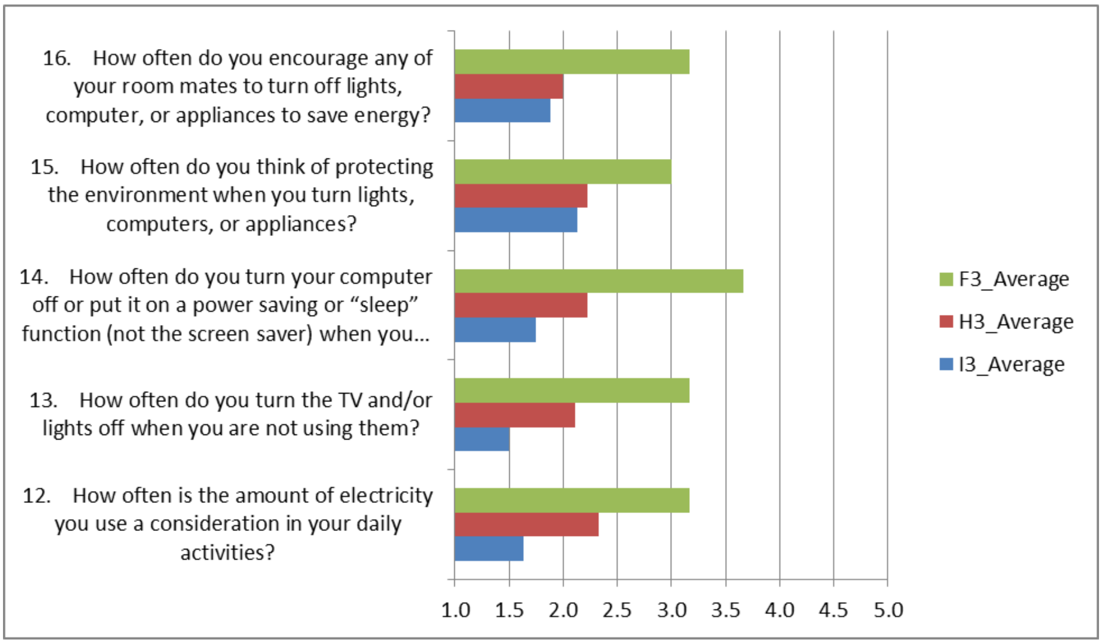

Figure 6.9 User acceptance of energy abatement initiatives at third rotation

Group I believes that every time coal, oil, or gas is used it contributes to climate change (Q19). These responses were neutral and represent 75%. Group I's lowest choice was for *How often do you turn your computer off or put it on a power saving or "sleep" function (not the screen saver) when you are not using it* (Q14).

Group F's highest responses were for *Carbon Dioxide is the primary gas responsible for the GHG effect* (Q21). A majority (83%) reported neutral. In contrast, the lowest choice for *Human induced climate change is occurring at some level* was for Q17. These responses were neutral and represent 50%.

Group H's highest responses were for *Carbon dioxide is the primary gas responsible for the GHG effect* (Q21). These responses of *strongly agree* represent 33%. Group H's lowest choice was the same as Group F for Q17: *Human induced climate change is occurring at some level*. These responses of *strongly agree* represent 66%.

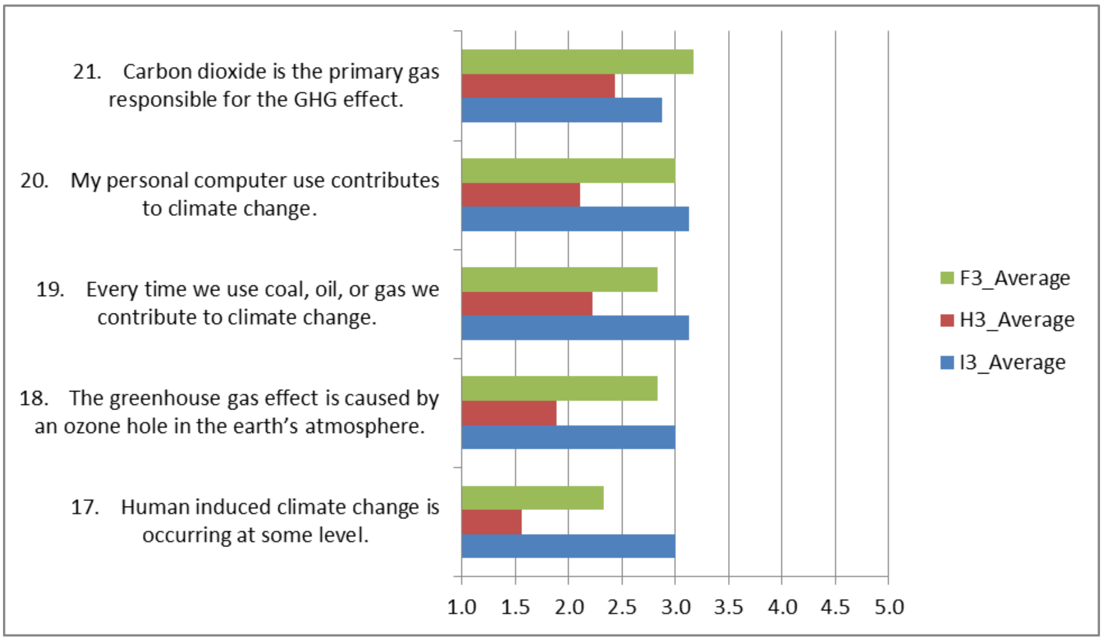

Figure 6.10 Behavioural aspects related to knowledge and greenhouse effect on climate change at third rotation

Proposition three (P3) states that: *"Users' energy management knowledge does affect users' behaviour to change their energy usage"*. The surveys were given to respondents three times during the rotation periods. Within the three groups, the results showed stability in two rotations in blocks F and H in the first and second rotations (Figures 6.3 and 6.6). The results indicate that user knowledge of energy use does not impact on users' behaviour as a result of the interventions from rotation to rotation. Therefore, Proposition Three (P3) is **not supported**.

Attitudes to energy use and their impacts on behavioural change were analysed and identified in each rotation to establish the influence that can be effectively made to energy savings and emission reductions. Changes in attitudes were measured to reflect actions relating to the interventions.

Proposition Four (P4) states that: *"There are no impacts from users' attitudes on energy saving initiatives".* The results indicate that the attitudes of users of energy, as a result of changes in technology, changed from rotation to rotation (Figures 6.2, 6.5 and 6.7). In addition, no interventions showed changes in the behaviour of users in block F that were significant to saving energy. Therefore, Proposition Four (P4) **is not supported.**

Proposition Five (P5) states that: "*There are no impacts of user acceptances of energy abatement initiatives on MACC methodology applied".* The findings indicate that the users' acceptance of energy abatement options on the MACC method regarding technology changes changed from rotation to rotation. Some of these users' responses show stability in two rotations but changes in the next rotation; in other cases, users' responses changed from the first rotation to the second rotation but were stable in the third rotation, and details are included in Figures 6.3, 6.6 and 6.8. Thus, Proposition Five (P5) is **not supported.**

6.5 Summary

In summary, this chapter contributes to at least three aspects of research regarding the assessment of behavioural changes. First, it presents one of the first empirical studies related to users' energy management knowledge and confirms that it does affect users' behaviour to change their energy usage. Second, it presents research impacts on users' attitudes to energy saving initiatives. Third, it establishes the importance of the impact of user acceptance of energy abatement initiatives on MACC methodology applied. The results of this chapter provide strong support for organisations. The findings of this chapter also support the proposition (P1) which purports there are differences between estimated (theoretical) and actual MACC models at an organisation level. Hence, more savings could come from educating people in best practice for energy management than via the installation of high technology devices such as sensor-based tubes. Chapter 7 provides further discussion regarding the findings presented in this chapter. Specifically, Chapter 7 answers each research question and addresses the overall research problem.

CHAPTER 7: CONCLUSION

7.1 Introduction

The previous chapter reported the results from the analysis of the qualitative findings from this study. This chapter provides a discussion of the results from the quantitative and qualitative studies, and refers to the literature and the study questions in addressing the key focus of the research. Finally, contributions made by this research to the literature, practice and methodology are highlighted. The thesis concludes by determining the limitations of this research and suggesting areas for future research. Also, the chapter sets out the conclusions for the research problem outlined in Chapter 1. The outline of this chapter is as follows (Figure 7.1):

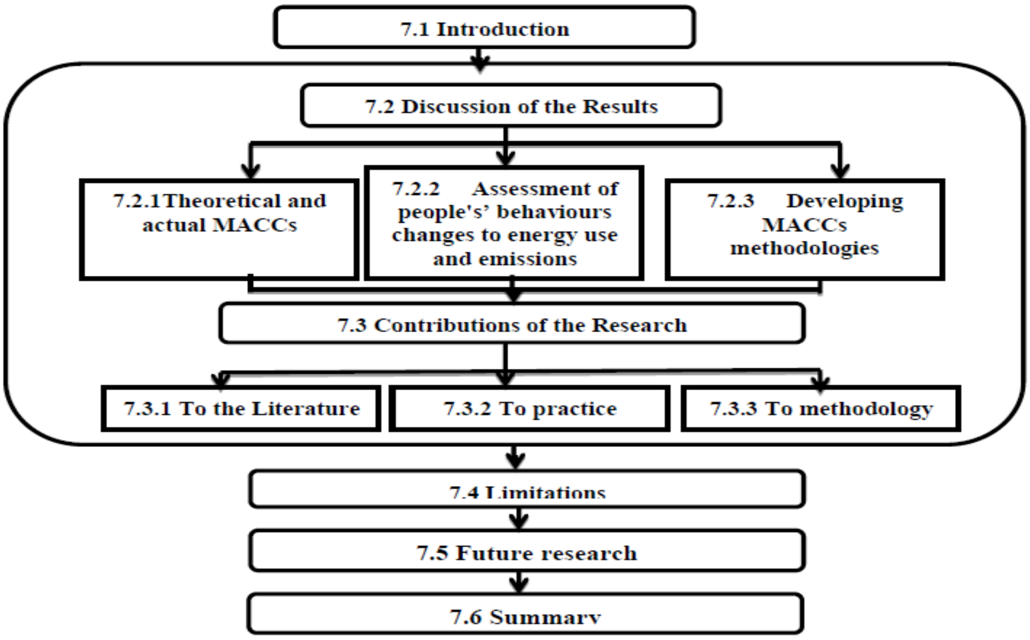

Figure 7.1 Structure of Chapter 7

7.2 Discussion of Findings

The best examination of the main findings from this research is through a return to the purpose of the questions that underlie the research. The purpose of the research is to investigate whether organisations can identify appropriate methods and apply them to MACC. Reducing an organisation's energy use and GHG emissions at theoretical and actual levels depends on MACCs using more accurate methods. Assessment of people's behavioural changes relating to energy use and climate change has been identified. Development of MACCs' methodology approaches, in order to be consistent and appropriate at an organisational level, are provided. The two main research questions of study addressed in this research are: **RQ1 Can MACCs provide an accurate and simple interpretation of relative and total abatement costs for energy abatement?** and **(RQ2) Does user behaviour resulting from abatement activities impact on MACC methodologies?**

The following five sub-research questions have been formulated in order to investigate the main research issue:

SQ1: Are there any differences between estimate (theoretical) and actual MACC models at an organisation level?

SQ2: Are there any shortcomings in the MACC methodology?

SQ3: Does users' energy management knowledge affect their behaviour to change their energy usage?

SQ4: What impacts do users' attitudes have on energy saving initiatives?

SQ5: To what extent does user acceptance of energy abatement initiatives have an impact on MACC methodology applied. The following section discusses the results from the study.

7.2.1 Theoretical and actual MACCs

The findings show that maximum abatement potential and cost-effectiveness are quantified by measuring the costs, benefits and the time of costs and benefits, calculating the NPV of project costs and returns, and expressing costs in terms of A$2009 for the MACC. The abatement for all the options of mitigations were summarised to provide a total abatement potential up to 2020. Each option was added to the graph in order of their cost-effectiveness. MACC was created using Excel software.

The results of this research indicate that there is an attempt to include theoretical MACCs in environmental policy. Theoretical MACC is not a difficult issue for business. It is a tangible and easy tool, but it needs to be used with caution during application. There are concrete examples of what business does to save energy and emission reduction; some organisations apply some options of conduct that include MACC-related criteria. The dominant activity now, however, is presenting MACC for acceptance by stakeholders by discussing how using MACC can help to facilitate protection of the environment from available options. This study is similar to the study conducted by (Wells & Hansen 2008) which found that electricity use at Macalester College in the USA represented the greatest amount of emissions on campus (annually 70-80%).

It was found there was an estimated MACC under the kind of conditions that are relevant to current policy discussions. This study presents graphs as an example set of options for USQ and provides data presented in Figure 5.8 of Chapter 5. Technologically, MACC's details can also help in the context of research, development and deployment policies by providing insights into the marginal abatement cost of technologies and can provide an indication about the necessary level of energy use and emission reduction in order to allow large scale deployment.

Options of discount rates depend on viewpoints that are analysed via MACC. If assessment of mitigation potential and costs of a company are related to social considerations, the private discount rate is the most appropriate. If nothing is done to

MACC from the point of view of the government, it would be more accurate to use a discount rate that includes criteria for hybrid public and private sectors. In fact, the interaction between all the actors, the government and the private sector is a substantial point for the definition of reduction policies.

Another important finding of this study indicated that the total maximum abatement potential of theoretical mitigation was measured and included in this analysis and amounted to 90.90 thousand tonnes of CO_2e. This potential comprised four options: Option A—9.50 thousand tonnes of CO_2e was accounted for by measures that contained benefits and costs (Insulation - College Buildings, V-Kool - Academic buildings - Set-point revised - Academic building lighting & Occupancy Sensor) - 1.6MWe photovoltaics, Solar thermal for Residential, 500kL Thermal Energy Storage). Option B—a further 17.20 thousand tonnes of CO_2e was accounted for by two measures (0.5MWe - Wind Power) with a marginal abatement cost in excess of, but within the uncertainty range of that projected for 2020. Together, these cost-efficient measures represent a potential reduction in GHG emissions. Option C—25.20 thousand tonnes of CO_2e was accounted by (1MWe Tri-generation). Finally, Option D—39.00 thousand tonnes of CO_2e was considered to be cost-effective and was accounted for by measures (0.5MWe Wind Power, plus 1MWe Tri-generation), that revealed a marginal abatement cost well in excess of the national price of carbon.

As a result of the project, USQ in the theoretical stage obtained an understanding of energy saving and decreasing carbon emissions and at a later time developed and consolidated the management methodology necessary to achieve a continuous reduction of emission sources. In particular, it has now recognised the importance of providing appropriate alternative energy use via efficient and low-carbon infrastructure systems. In addition to operational improvements and infrastructure that have been put forward to consider as options, there has been a significant evolution of professional knowledge and experience within the various staff members of USQ in dealing with the management of carbon reduction.

The quantitative results of this study found that there is a significant saving in energy use at the theoretical level of analysis. There are several of studies that support these results (Baker et al. 2009; Böhringer & Rutherford 2008). The quantitative results of Fromme (1996) demonstrate that energy saving measures of individual task lighting also led to significant reductions. Furthermore, about 40 more energy saving measures have been identified that add up to further important potential savings. The findings suggest that reducing the definition of cost (technical change) is one of the reasons for negative control costs, and any abatement measures that could be used at the same time reduce emissions and save money. This issue has been the focus of heated debate as it is not in line with traditional economics. Studies have addressed these issues in the past. Such studies attempted to explain the gaps between theoretical reduction potential and actual reduction potential (DeCanio 1993; Jaffe & Stavins 1994; Kesicki & Strachan 2011).

The results of the project (F, I and H blocks) at USQ for the actual usage of data provided an understanding of energy savings and decreasing of emissions, as well as cost. Using actual data from the project validated and reduced uncertainty related to the MACC method. This information contributed to developing the enhancement to

MACC's methodology for this study, which was necessary to utilise MACC's approach to develop a low GHG plan.

The first rotation of Block F's actual consumption was 416.89 KWh equivalent to 0.37103 CO_2e, costing $65.62. The second rotation decreased from the first actual consumption to 264.67 KWh equivalent to 0.23556 CO_2e, also decreasing the costing to $41.66. In the third rotation, the actual consumption decreased to 193.08 KWh equivalent to 0.17184 CO_2e, also decreasing costing to $30.39. Because all these rotations in F Block used T8 lighting, the savings of energy, reductions of emission and costing were not due to any technical change or interventions. The reductions were due totally to behavioural changes of the participants in the case study.

In the first rotation Block I's actual consumption was 407.59 KWh equivalent to 0.36276 CO_2e, costing $64.15. The second rotation decreased from the first actual consumption to 245.23 KWh equivalent to 0.21826 CO_2e, decreasing costing to $38.60. In the third rotation, the actual consumption decreased to 180.47 KWh equivalent to 0.16062 CO_2e, decreasing costing to $28.41. These reductions happened because of technical changes and interventions. The first rotation started with T8 lighting. The second rotation changed from T8 lighting to LED lighting. The third rotation changed from LED lighting to T5 lighting. Because of these changes in lighting during these rotations, the savings of energy, reductions in emission and costing were due to interventions with technical changes, but also included behavioural changes.

In the first rotation Block H's actual consumption was 702.53 KWh equivalent to 0.62526 CO_2e, costing $110.58. The second rotation decreased from the first actual consumption to 426.54 KWh equivalent to 0.37933 CO_2e, decreasing costing to $67.09. In the third rotation, the actual consumption decreased to .61 KWh equivalent to 0.28000 CO_2e, decreasing costing to $49.52. These reductions happened because of technical changes and interventions. The first rotation started with T8 lighting. The second rotation changed from T8 lighting to T5 lighting. The third rotation changed from T5 lighting to LED lighting. Because of these changes in lighting during these rotations, the savings of energy, reductions of emission and costing were due to interventions with technical changes, but also included behavioural changes.

The results of the study indicate that there was different energy consumption at the three rotations in theoretical and actual stage. This is partly in line with the consumption at theoretical level with previous empirical studies undertaken by Majcen et al. (2013) and Sanstad and Howarth (1994). This study has found reductions of 23%. This reduction agrees with other perspectives which relate to other causes such as behavioural issues and recognition of barriers (Geller et al. 2005; Sorrell 2004). Overall, the findings indicate that LED's have the most consistent light output and colour rendition.

This study also adopted a qualitative approach in analysing the data obtained from the conducted interviews. This approach has been applied to answer development methodologies. The insights, views and opinions of the participants were tested in this study. The outcomes of the conducted interviews disclosed that the advices and insights of experts and managers can be helpful in improving environmental issues with respect to improvement methods for environmental conservation.

7.2.2 Developing MACC methodologies

The notable results are displayed from surveys and, where available, highlights any significant comparisons between samples. Questions raised by previous studies have served as the motivation for this study.

In order to find a cost-effective way to develop methodologies for MACC, managers and experts on energy savings and reduction emissions within the respective firms were invited to express their views on plausible and cost-effective technologies that could be adopted into MACC projects. After intensive discussions (as shown from interviews in Chapter 6), respondents who presented several options regarding technologies were selected for further study.

The results of the study indicated that there is growing support for MACCs. When MACC depends on real information and takes into consideration the importance of NPV which creates significant developments for MACC's approach, there is a decrease of caveats, as demonstrated in the study conducted by (Jorge et al. 2005). This clearly conveys the most important finding of this study. This development has led companies to be more committed and responsible in their approach to energy saving and emission reductions. In addition, using more accurate data to operate MACC gives it credibility, which enhances MACC as a useful tool to help firms identify cost effective and appropriate ways to abate emissions.

Finally, given the importance of mitigating the effects of climate change, the way MACC has been developed can be applied to carbon reduction from energy use. Such an outcome provides a benchmark value for quantitative policy analysis.

7.2.3 Assessment of people's behavioural changes to energy use and emissions

Users' attitudes towards energy saving initiatives

The evaluations of results from the participants are: Students in three groups indicated little previous connection to environmental issues through a degree program or an environmental organisation. Many participants indicated learning about environmental issues through the usage of their electricity and climate change. A higher percentage of participants in the three groups residing in the three blocks (F, I and H) indicated changing behaviours in their usage of lights and appliances regarding saving energy.

The results demonstrate that users' attitudes have positive impacts on behavioural changes to energy saving initiatives. Participants implied that attitude to saving energy and using their equipment is determined by their belief in reducing energy usage and emissions. This finding is supported by previous studies undertaken by Allen (2012); Moisander (1996); Valkila and Saari (2012).

Users' knowledge affects their behaviour to change their energy usage

This study confirms that knowledge has positive impacts on change in energy-use behaviour and reduction in consumption. Understanding the interventions led to considerable reduction; as did a person's perceived social weight to perform or not to perform environmentally friendly behaviour. The results show that knowledge has an important impact on users' behaviour relating to energy saving because the respondents demonstrated significant potential to participate. Most students in the three groups, before and after this study was conducted, indicated a strong belief that climate change exists and is important. This evidence supports previous studies by Hargreaves et al. (2010); Marcell et al. (2004); Oleckno (1995); and Steg and Gifford (2005). It would appear that energy users may have similar behavioural patterns when they start to acquire environmental knowledge. As a consequence, some people assume that the government has adequately addressed climate change by placing restrictions or industry regulations on production in some large factories. In fact, many of the GHG inventories reveal that the significant sources of emissions in most communities are the result of individual behaviour choices.

User acceptance of energy abatement initiatives have an impact on MACC methodology applied

A change in behaviour is often an effective way to create a climate in which a new style or modification of the behaviour gains familiarity and acceptance. It could condition people to feel that what is required of them or snatched from them is useful, desirable or meaningful (Bogart, 1978).

This empirical study shows that user acceptance of energy abatement initiatives has positive impacts on behavioural intentions to interventions used for reducing energy use and emissions of GHGs. This evidence is very significant in that perceived behaviours are actual elements that have affected the way users accept abatement initiatives. This finding is in line with several studies conducted by Davis (1993) and Ulli-Beer et al. (2010). The benefits from any kind of new technology requires consistent use (Brown et al. 2002).

This research uses behavioural dimensions of energy users relating to technical changes. The findings are similar to previous studies that have revealed a relationship between energy consumption and energy user behaviour (Branco et al. 2004; Guerra Santin 2011; Sardianou 2007). Some studies have investigated the relationships between behavioural patterns and energy user characteristics in order to build user profiles based on the type of group (Lindén et al. 2006; Sardianou 2008). The identification of group types, such as energy users, leads to more accurate estimates of the energy that could be saved through targeted measures and, at the same time, assist energy users to predict quantity energy consumption. An important addition to the results of this study is that energy users significantly contribute to behavioural changes. This additional result is more critical than technical intervention, which was previously used.

7.3 Contributions of the Research

7.3.1 To the Literature

This research provides important insights, particularly in promoting energy saving and emission reduction perceptions at organisation level. The contributions of this study are three-fold. Firstly, the study provides empirical evidence by using MACCs' approach at the theoretical stage. This evidence can influence and drive individual companies even at levels lower and less extensive than this research case study provides. Secondly, this study developed and enhanced the usage of MACC's approach. The findings can be used to encourage organisations to continually improve their sustainability performance, and allows a continuum for monitoring a broader and more inclusive sustainability performance that provides more appropriate and accurate decision-making. Thirdly, the study is crucial to understanding internal and external drivers that impact the development of actual data to obtain appropriate benchmarks that can be applied to associated industries.

This study is the first attempt to combine a theoretical MACC and actual MACC, as well as applying a behavioural change approach to integrate management of energy use and emissions. The initial aim of the study was to create more accurate cost accounting data regarding the environment that helps decision-makers and different stakeholders to adopt a more trustworthy method that reveals energy savings and GHG reductions. This study has focused on the MACC approach, and addresses organisation and stakeholder concerns, and includes societal interests such as user behaviour. Due to the inclusion in this study of user behaviour, the MACC method was further developed to include this important research aspect. The implications of the study relating to MACC method using actual data is likely to contribute to both the literature and practice.

7.3.2 To practice

The implications of this study are: the study provides an approach for all organisations to implement reductions in GHGs relating to stationary energy use. Methodologically and methodically, the study was reinforced by the importance of the need to conduct in-depth field research and incorporate such research into appropriate accounting and environmental methods for abatement assessment. Therefore, enhancing MACC's methods for this study provides organisations with a more extensive management accounting mechanism to contribute to practice. Firstly, this improved methodology provides findings that can be adopted to reduce concerns about the effects of GHG abatement strategies by business, and also provides evidence that the MACC approach is valid. Secondly, it demonstrates ways in which a business can be encouraged to continually improve its energy management. Organisations have the potential advantage of applying MACCs to help reduce energy usage and emissions. Finally, the study is expected to help regulators in regions understand the role of MACCs which, in turn, will help them in setting future regulations and strategies.

The actual consumption of energy in 3 rotations in block F shows considerable savings to lighting compared with theoretical energy consumption of lighting. This happened without any intervention or change in technology. The study has found that this change in the reduction of energy use was due to the change of behaviour in the residential respondents in F block. This notable finding from the results of this study is shown in Table 5.5.

7.4. Limitations

Research, including this study, has some limitations. Most limitations relate to data collecting and analysis approaches. This research is not an exception.

The case study provides observations, information and learning that can be applied in other organisations seeking to implement a carbon reduction strategy by applying the MACC tools. The outcomes of the study cover the technical changes, behavioural changes and management accounting aspects of carbon reduction. Although the GHG Protocol requires that at least scopes 1 and 2 emissions are reported for any GHG inventory, this study used indirect emissions, which mean scope 2. The implications of this research are that this study has provided empirical evidence on saving energy, and reduction emissions for an individual firm at a level of complexity provided in the case study. Secondly, it considers behavioural change related to energy users and its significance from an external and internal perspective. Thirdly, it demonstrates methods in which an organisation can be encouraged to continually improve energy usage and abatement emissions. As this research focused on one organisation in the education sector, the findings may not be representative of all organisations or all businesses. Therefore, limited generalisations can be made from the findings.

7.5 Future research

The findings in this research indicate some areas of possible future study. The study provides increasing prominence to some interesting topics for further research and more detailed examination. As mentioned above, many of the individual measures require additional research, in particular the possibility of developing a method for saving energy. Further research should focus on expanding mitigation measures of non-technical change and infrastructures for emission reductions. This study has drawn attention to an important area (behavioural changes) that can provide considerable energy savings and emission reduction. The proposed methodology in this research could be supplemented by more quantitative methods of information collection. One approach could be conducting an online survey prior to interviews to capture a wider participant base from which to elicit primary data. However, any quantitative information collection should only be viewed as supplementary evidence, as the qualitative interviews have proven essential in understanding the real barriers. An alternative option could be to conduct a more detailed quantitative study within particular companies where access is provided. This could help in enhancing the validity of the estimates and implications of the effect of using MACC. It is recommended that more research be undertaken to investigate these issues in other areas, especially in less developed countries.

7.6 Summary

This study has contributed to both theoretical and practical studies in the area of energy saving and emission reductions; and has established the implications of these impacts on environmental protection at corporation level. Furthermore, the study will open new windows for future study focusing on organisations because it is often argued that local or domestic firms have faced difficulties in the past when attempting to find an appropriate method to achieve abatement of energy consumption and GHGs emissions.

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APPENDICES

Appendix 1: Calculation of MACC

For each possible abatement project you will need:
1-Full cost of implementation of the project ($)
2- Investment timeframe (years)
3- Amount of GHG emissions saved over investment timeframe (usually in tonnes of CO2-e)
4- Amount of money that will be saved from the project ($)

- MACC CALCULATION PROCESS:

1. Conduct an energy audit or similar process to identify multiple projects that can reduce GHG emissions. The four above points needed for the information that is required from this process.
2. Assign an investment timeframe.
3. Calculate NPV for each project.
4. Calculate MAC for each project.
5. Enter each project's MAC into cost curve graph.

Calculate the marginal abatement cost**,** which is the NPV divided by the CO_2 savings over the life of the project. Again a negative cost means that there is a saving from this abatement project.

Marginal Abatement Cost (MAC) ($/t CO2-e) =

Net Present Value ($)/GHG emissions saved from abatement project (t CO_2-e) during investment timeframe (Riedy 2003_ENREF_390).

Simple Net Present Value (NPV) =
Cost of implementing abatement project - Savings from abatement project during investment timeframe.

Plot the marginal abatement cost curve. To plot the graph you will need to sort your project in the order of increasing abatement cost. You will also need to calculate the cumulative savings. The marginal abatement cost curve can then be displayed graphically.

The steps involved in the derivation of a cost curve for emission reduction are:
1. Identify sources of the relevant air pollutants, and quantify emissions of air pollutants from each source.
2. Establish what level of abatement is currently used in the AU, and identify where current or emerging technologies or techniques are available which could give further improvements in the level of abatement.
3. Quantify costs for implementing these further abatement measures.
4. Estimate the effectiveness of these further abatement measures at reducing emissions.
5. Combine cost and effectiveness data to provide a list of options ranked by marginal cost per unit abated.

Appendix 2

A survey Instrument of users' acceptance technological change

The following questions relate to your attitudes towards energy conservation. Please indicate your answer by ticking the relevant box.

1-Overall, how would you rate your attitude towards energy conservation?

- ☐ Very conscious
- ☐ Conscious
- ☐ Neutral
- ☐ Not conscious
- ☐ Not conscious at all

2-How would you rate your attitude towards environmental issues and environmental conservation?

- ☐ Very conscious
- ☐ Conscious
- ☐ Neutral
- ☐ Not conscious
- ☐ Not conscious at all

3-To what extent do you agree or disagree with the following perceptions: currently, we as a society are acting sufficiently to conserve energy so as to make sure that our future generations are not affected

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agrees nor disagrees
- ☐ Disagree
- ☐ Strongly disagree

To what extent do you agree or disagree with the following perceptions

4- It is probably unrealistic to expect USQ students to alter their behaviour to prevent global climate change.

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agrees nor disagrees
- ☐ Disagree
- ☐ Strongly disagree

5-The Australia government should take an active role in the global effort to curb the problem of rapid climate change. To what extent do you agree or disagree with the following perceptions

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agrees nor disagrees
- ☐ Disagree
- ☐ Strongly disagree

-To what extent do you agree or disagree with the following statements

(1= strongly agree, 2= Agree, 3= neither agrees nor disagrees, 4= disagree, 5= strongly disagree)

Statement	1	2	3	4	5
6-Environmental issues are very important to me.					
7-The average USQ student is not at all concerned with the issue of climate change.					
8-There is little action that I can take to reduce the threat of climate change					

The following multiple choice questions address student perceptions with regard to the following areas:

- Reducing overall electricity consumption;
- Worthwhile incentives for electricity reduction;
- Awareness and use of the computer power management functions;
- Behaviours they are likely to undertake to prevent GHG emissions.

9-Perceived benefits of turning off computer, TV, or radio (choose one of the following options only)

☐ -Reducing noise
☐ -Reducing the threat of climate change
☐ -Making TV/computer last longer
☐ -Reducing air pollution
☐ -Reducing the cost of room and board for future students
☐ -Saving USQ money
☐ -Protecting the ozone layer
☐ -Protecting the environment

10- Incentive most likely to make you reduce electricity use (choose one of the following options only)

☐ -$20 reduction in bursar’s bill
☐ - Knowing you are doing good for the environment
☐ - Having to pay for your electricity use
☐ - A barbecue for your dorm
☐ - Recognition from dorm mates
☐ - Knowing it’s good for your appliances
☐ -Knowing that you are not being wasteful
☐ - Incentive most likely to make you reduce

11-Actions you are most likely to take to reduce the impact of climate change (choose one of the following options only)

- [ ] -Walking instead of driving
- [ ] -Switching to fluorescent bulbs
- [ ] -Voting for legislators that support pollution controls
- [ ] -Asking for more energy efficient policies at USQ
- [ ] -Recycling
- [ ] -Turning off your computer at night and when not in use
- [ ] -Flying less
- [ ] -Eating less red meat
- [ ] -Buying a more fuel efficient vehicle
- [ ] -Enabling power management function on computer

- Student behaviour with respect to electricity use in their suites

To what extent do you agree or disagree with the following statements

(1= Very conscious, 2=conscious, 3= Neutral, 4= Not conscious, 5= Not conscious at all)

Statement	1	2	3	4	5
12-How often is the amount of electricity you use a consideration in your daily activities?					
13- How often do you turn the TV and/or lights off when you are not using them?					
14-How often do you turn your computer off or put it on a power saving or “sleep” function (not the screen saver) when you are not using it.					
15-How often do you think of protecting the environment when you turn lights, computers, or appliances?					
16-How often do you encourage any of your room mates to turn off lights, computer, or appliances to save energy?					

- Student’s knowledge of electricity generation, the greenhouse effect, climate change, and the student’s confidence in their knowledge.

To what extent do you agree or disagree with the following statements

(1= strongly agree, 2= Agree, 3= neither agrees nor disagrees, 4= disagree, 5= strongly disagree)

Statement	1	2	3	4	5
17-Human induced climate change is occurring at some level.					
18-The greenhouse gas effect is caused by an ozone hole in the earth’s atmosphere.					
19-Every time we use coal, oil, or gas we contribute to climate change.					
20-My personal computer use contributes to climate change.					
21-Carbon dioxide is the primary gas responsible for the GHG effect.					

Appendix 3

Interview list for firm energy and emissions reduction to MACCs

Interviews questions

Question 1: Can you tell me about what actions your organisation is taking to save energy.

a. Is this reduced overall CO_2 emissions?
b. Is this driven by a need to save cost?
c. Or is it a desire to reduce carbon footprint?

Question 2: Does your organisation have targets for CO_2 Reduction and what are they? And when they set?
Question 3: Have you met the targets set for CO_2 reduction? If so by how much?
Question 4: What is your motivation for CO_2 reduction? For example:
-Achievement of Voluntary Target in an Industry.
- Favourable Treatment from Government and Financial Institutions.
- Ensuring Business Partners from Home and A broad.
- Social Responsibilities of Companies (Improvement of Company Image).
- Others.
Question 5: Do you know about or use marginal abatement cost curve (MACC)?
Question 6: Have you identified any marginal abatement cost for CO_2 reduction strategies?
Question 7: Could you explain what method and /or software did you use to generate MACC?
Question 8: Could you explain what sectoral assumptions (education) that your organisation depends on (explain)?
Question 9: Can you explain what assumptions you made in your MACC methodology?
Question 10: Do you measure results of intervention identified using MACC?
Question 11: What benefits and barriers have you encountered in introducing and using MACCs?
Question 12: How much importance and support have you received from top management for:
-Energy saving initiatives?
-Carbon reduction strategies?
-Use of MACCs to guide management decision-making?
Question 13: What is the most optimal strategy for organisation to maintain sustainability**?**
-Change behaviour (switching energy usages).
-Change technology (innovation/ intervention).
Question 14: Are MACC useful for identifying Least- cost or best reduction strategies?
Question 15: Is there one function that fits all organisations and sectors?
Do you have any additional useful information relate to MACC?

Appendix 4

Plain Language Statement

University of Southern Queensland

USQ
AUSTRALIA

The University of Southern Queensland

Plain Language Statement

TO: Participants

Full Project Title: Utilizing a marginal abatement cost curve approach to develop a low greenhouse gas plan: Case studies of energy management in multiple sectors across a rural region (Toowoomba-Australia)

Student Researcher: Ali Ahmad Almihoub

REF No: H12REA047

I am Ali Ahmad Almihoub, PhD student, Faculty of Business and Law, University of Southern Queensland, Queensland, Australia. My research projects is about assessing and developing a low greenhouse gas plan using case studies of energy management in multiple sectors across a rural region (TOOWOOMBA). I would like to invite you to take part in this research project.

1. Purpose of Research

The aim of the study is to develop a marginal abatement cost curve (MACC) methodology that uses actual net saving effects from stationary energy management interventions to validate a MACC or MACCs, across firms in the same sector as well as across sectors in one region.
Therefore, the study seeks to:
-Compare MACC estimates with actual outcomes at firm level.
-Determine the extent of variation from average estimates contained in regional and or sectoral level MACCs.
-Comparing the different methodologies and assumptions when estimating MACCs.

2. Procedures

Participation in this project will involve

1- Support and endorsement by senior management team or broad to participate in this project.

2- A contact person in the organisation with I can liaise.

3- Access to data on energy usage of all forms in both dollar and volume (e.g. kilowatts) terms.

4- Provision of funds to purchase and install retrofit interventions based on agreed area(s) of energy considered as providing the most cost saving per tonne of CO_2 emissions.

5- Ongoing commitment to provide data once the energy saving retrofit is complete; the length of time data will be collected is negotiated on a case by case basis.

6- Observations of electricity use and changes made by interventions (equipment).

7- Face to face interviews with engineers and acceptance of managers.

8- Semi-structured questions will be used with engineers and managers.

9- Opportunity to present findings from the project to senior management.

10- Approval to publish findings with organisation's name included but with organisation reviewing paper before publication.

No potential risks to the participants are expected.

3. Confidentiality

Any documents obtained will be stored safe in a filing cabinet. The digital data will be stored on a separate and safe disk with password rather than on a personal computer's hard drive. Data will be stored for five years and then destroyed.
Any information obtained in connection with this project that can identify you will remain confidential. It will only be disclosed with your permission, subject to legal requirements. If you give us your permission by signing the Consent Form, I plan to share and discuss findings with international scientific community in conference and seminars and publish in journals.
In any publication, information will be provided in such a way that you cannot be identified. Consolidated data will be presented in any publication.

4. Voluntary Participation

Participation is entirely voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. Any information already obtained from you will be destroyed.

5. Queries or Concerns

Should you have any queries regarding the progress or conduct of this research, you can contact the principal researcher:

Ali Ahmad Almihoub

Faculty of Business and Law, University of Southern Queensland (USQ),
Toowoomba campus
Address: 41 Wuth Street, QLD-4350, Toowoomba, Australia
Ph: 46312273 and Mobile: +403124114(after hours)

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer on the following details.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees
University of Southern Queensland
West Street, Toowoomba 4350
Ph: +61 7 4631 2690
Email: ***ethics@usq.edu.au***

Appendix 5

Information and Consent Form for Participants

USQ

AUSTRALIA

University of Southern Queensland

The University of Southern Queensland

Consent Form

TO: Participants

Full Project Title: **Utilizing a marginal abatement cost curve approach to develop a low greenhouse gas plan: Case studies of energy management in multiple sectors across a rural region (Toowoomba-Australia)**

Student Researcher: **Ali Ahmad Almihoub**

REF No: H12REA047

- I have read the Participant Information Sheet and the nature and purpose of the research project has been explained to me. I understand and agree to take part.

- I understand the purpose of the research project and my involvement in it.

- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.

- I confirm that I am over 18 years of age.

- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

- I understand that I may be included in photographs during the study.

Name of participant……………………………………………………………………......

Signed…………………………………………………….**Date**……………………….

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer on the following details.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees
University of Southern Queensland
West Street, Toowoomba 4350
Ph: +61 7 4631 2690
Email: ***ethics@usq.edu.au***

Appendix 6

Ethics Clearance

University of Southern Queensland

TOOWOOMBA QUEENSLAND 4350
AUSTRALIA
TELEPHONE +61 7 4631 2300

CRICOS: QLD 00244B NSW 02225M

www.usq.edu.au

OFFICE OF RESEARCH AND HIGHER DEGREES
Ethics Committee Support Officer
PHONE (07) 4631 2690 | FAX (07) 4631 1995
EMAIL ethics@usq.edu.au

Sunday, 6 May 2012

Ali Almihoub
Email: ali.almihoub@usq.edu.au

Dear Ali

The Chair of the USQ Fast Track Human Research Ethics Committee (FTHREC) recently reviewed your responses to the FTHREC's conditions placed upon the ethical approval for the below project. Your proposal now meets the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* and full ethics approval has been granted.

Project Title	Utilising a marginal abatement cost curve approach to develop a low green house gas plan: Case studies of energy management in multiple sectors across a rural region (Toowoomba-Australia)
Approval no.	H12REA047
Expiry date	01.08.2013
FTHREC Decision	**Approved**

The standard conditions of this approval are:

(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) advise (email: ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) make submission for approval of amendments to the approved project before implementing such changes
(d) provide a 'progress report' for every year of approval
(e) provide a 'final report' when the project is complete
(f) advise in writing if the project has been discontinued.

For (c) to (e) forms are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement (2007)* may result in withdrawal of approval for the project.

You may now commence your project. I wish you all the best for the conduct of the project.

Melissa McKain
Ethics Committee Support Officer
Office of Research and Higher Degrees

Appendix 7

Available options for USQ technical change for saving energy and emissions

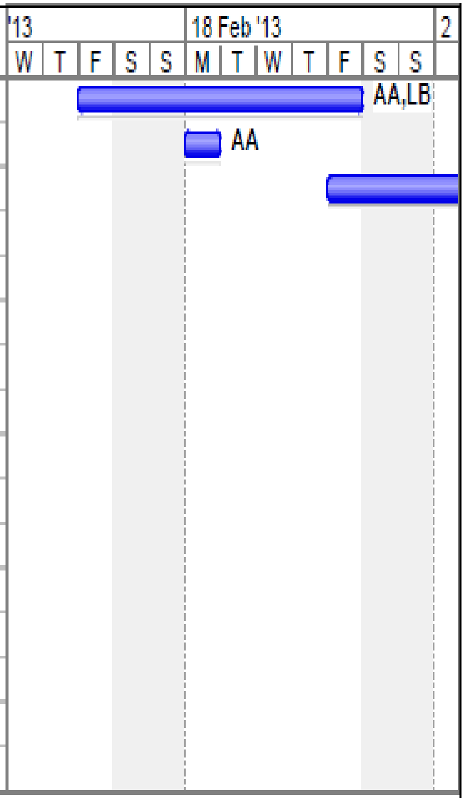
Technology	Description	Capital Cost	Annual cost (Maintenance, etc)	Potential Carbon Abatement	Carbon emissions	Cost of Abatement	Conservative)				Sitewide percentage
							Conservative	Optimistic	Conservative	Optimistic	
Units		$	$/year	t/year	t/year	($/tonne/year)	Years	Years	$	$	%
Business as Usual		N/A	N/A		13,711	N/A	N/A	N/A	N/A	N/A	0%
Option 1	Insulation - College Buildings V-Kool - Academic buildings Set-point revised - Academic building Lighting & Occupancy Sensor 1.6MWe photovoltaics Solar thermal for Residential 500kL Thermal Energy Storage	$ 11,620,000	$ 4,600	4,769	8,942	-$ 70	13.9	11.6	$ 962,000	$ 8,840,822	35%
	Insulation - College Buildings V-Kool - Academic buildings Set-point revised - Academic building Lighting & Occupancy Sensor	$ 4,020,000	-$ 45,300	2,260	-	-$ 97	10.6	$ -	$ -	$ -	
	1.6MWe photovoltaics	$ 6,600,000	$ 45,200	2,229	-	-$ 13	10.4	9.1	$ 3,353,000	$ 10,211,698	
	Solar thermal for Residential	$ 455,000	$ 4,600	253	-	-$ 31	11.7	9.4	$ 183,000	$ 858,258	
	500kL Thermal Energy Storage	$ 445,000	$ -	27	-	-$ 756	9.8	9.5	$ 215,000	$ 297,845	
Option 2	Option 1 plus 0.5MWe Wind Power	$ 16,645,000	$ 29,600	6,193	7,518	-$ 51.89	15.1	12.2	-$ 83,000	$ 11,694,792	45%
	Wind	$ 5,025,000	$ 25,000	1,424	-	$ 7	16.4	12.6	-$ 513,000	$ 3,325,499	
Option 3	option 1 plus 1MWe Tri-generation	$ 13,820,000	$ 67,400	6,429	7,282	-$ 141	14.1	12.0	-$ 56,000	$ 7,824,319	47%
	1MWe Tri-generation	$ 2,300,000	62,900	$ 1,660	-	-$ 396	3.4	3.2	$ 9,364,000	$ 21,353,000	
Option 4	Option 1 plus 0.5MWe Wind Power plus 1MWe Tri-generation	$ 18,845,000	$ 112,400	7,853	5,858	-$ 114	15.2	12.5	-$ 1,100,000	$ 10,818,289	57%
Carbon Neutrality	Option 4 plus Carbon credits	N/A	$ 184,744	$ 5,858	0	$ 28	N/A	N/A	N/A	N/A	100%

Pathways to Carbon Neutrality

Appendix 8

Energy case study Steele Rudd Lighting Trial

ID		Task Name	Duration	Start	Finish	Predecessors
1		Trial reading	6 days	Fri 15/02/13	Fri 22/02/13	
2		1st interview focus group	1 day	Mon 18/02/13	Mon 18/02/13	
3		Establish baseline	6 days	Fri 22/02/13	Fri 1/03/13	
4		Lighting Rotation	56 days	Mon 4/03/13	Mon 20/05/13	3
5		1st Rotation H block (leave as is T8's) FEMALE OCCUPANTS	126 days	Fri 1/03/13	Fri 23/08/13	
6		1st Rotation F Block (leave in T8's) BASELINE FEMALE OCCUPANTS	126 days	Fri 1/03/13	Fri 23/08/13	
7		1st Rotation I Block (leave in T8's) MALE OCCUPANTS	126 days	Fri 1/03/13	Fri 23/08/13	
8		2nd interview focus group SURVEY	6 days	Mon 2/09/13	Mon 9/09/13	
9		2nd rotation H block (change to T5's) FEMALE OCCUPANTS	20 days	Mon 26/08/13	Fri 20/09/13	5
10		2nd rotation F Block (leave in T8's) BASELINE FEMALE OCCUPANTS	20 days	Mon 26/08/13	Fri 20/09/13	6
11		2nd rotation I Block (change to LED's without sensors) MALE OCCUPANTS	20 days	Mon 26/08/13	Fri 20/09/13	
12		3rd interview focus group SURVEY	6 days	Mon 14/10/13	Mon 21/10/13	
13		3rd rotation H block (change to LED's without sensors) FEMALE OCCUPANTS	20 days	Mon 7/10/13	Fri 1/11/13	
14		3rd rotation F Block (leave in T8's) BASELINE FEMALE OCCUPANTS	20 days	Mon 7/10/13	Fri 1/11/13	
15		3rd rotation I Block (change to T5's) MALE OCCUPANTS	20 days	Mon 7/10/13	Fri 1/11/13	
16		Change all lighting back to base T8's	5 days	Mon 4/11/13	Fri 8/11/13	15



Appendix 9

Lux Reading and Verification Data

Block	Quantity of Lamps	F Block (Female) T8s' 1st Rotation Non-calibrated	F Block (Female) T8s' 1st Rotation Calibrated	F Block (Female) T8s' 2nd Rotation Non-calibrated	F Block (Female) T8s' 2nd Rotation Calibrated	F Block (Female) T8s' 3rd Rotation Non-calibrated	F Block (Female) T8s' 3rd Rotation Calibrated	F Block (Female) Lights Off Non-calibrated	F Block (Female) Lights Off Calibrated	**Notes**
Rm101	1	95	308	248	308	165	308	0	0.02	
Rm102	1	187	326	225	326	216	326	0	0	
Rm103	1	87	330	84	330	153	330	0	1	
Rm104	1	170	372	240	372	135	372	0	0.5	
Rm105	1	167	370	160	370	205	370	0	0.2	
Rm106	1	177	338	215	338	180	338	0	0.1	
Rm107	1	112	223	100	223	107	223	0	0.4	
Rm108	1	45	172	115	172	107	172	0	0.4	
Rm109	1	147	365	152	365	147	365	0	0.7	
Rm110	1	175	345	125	345	252	345	0	0.15	
Cor111	3	140	201	145	201	130	201	196	201	Influenced by external lighting
		100	170	109	170	126	170	168	170	
		90	208	143	208	144	208	200	208	
C.Rm112	2	310	433	177	433	225	433	426	433	
		344	382	144	382	263	382	403	382	
Toilet	4	390	206	611*	206	191	206	170	206	Influenced by external lighting
		320	146	523	146	295	146	123	146	
		110	564	730	564	400	564	524	564	
		165		123		49				
Laundry	2	345	515	165	515	477	515	508	515	Influenced by external lighting
		560	692	130	692	445	692	684	692	
Cor116	3	85	190	119	190	136	190	183	190	116 (F) block 1 lamp
		118	192	113	192	81	192	190	192	

Lux Reading and Verification Data

Block	Quantity of Lamps	I Block (Male) T8s' 1st Rotation	I Block (Male) T8s' 1st Rotation	I Block (Male) LEDs' 2nd Rotation	I Block (Male) LEDs' 2nd Rotation	I Block (Male) T5s' 3rd Rotation	I Block (Male) T5s' 3rd Rotation	I Block (Male) Lights Off	I Block (Male) Lights Off	**Notes**
		Non-calibrated	Calibrated	Non-calibrated	Calibrated	Non-calibrated	Calibrated	Non-calibrated	Calibrated	
Rm101	1	147	308	238	348	229	248	0	0.6	
Rm102	1	150	326	264	350	94	211			
Rm103	1	127	330	157	351	87	212			
Rm104	1	158	372	257	358	85	249			
Rm105	1	42	370	247	368	99	287	0	0.4	
Rm106	1	90	338	266	321	230	216	0	0.9	
Rm107	1	130	223	271	353	115	258	0	0.5	
Rm108	1	90	172	215	354	215	303	0	0.9	
Rm109	1	86	365	258	363	253	352	0	1.2	
Rm110	1	170	345	272	351	94	316	0	0.6	
Cor111	3	135	201	175	283	265	205			Influenced by external lighting
		112	170	162	218	149	207			
		74	208	174	212	185				
C.Rm112	2	275	433	177	333	244				
		190	382	263	354	262				
Toilet	4	125	206	334	263	228				Influenced by external lighting
		610	146	208	648	195				
		654	564	875	150	724				
		110		764	146	678				
Laundry	2	520	515	420	723	699	580	1056	1032	Influenced by external lighting
		310	692	443	603	304	1265			
Cor116	3	80	190	154	212	123	181	66	38	116 (F) block 1 lamp
		104	192	163	213	130				

Lux Reading and Verification Data

Block	Quantity of Lamps	H Block (Female) T8s' 1st Rotation	H Block (Female) T8s' 1st Rotation	H Block (Female) T5s' 2nd Rotation	H Block (Female) T5s' 2nd Rotation	H Block (Female) LEDs' 3rd Rotation	H Block (Female) LEDs' 3rd Rotation	H Block (Female) Lights Off	H Block (Female) Lights Off	**Notes**
		Non-calibrated	Calibrated	Non-calibrated	Calibrated	Non-calibrated	Calibrated	Non-calibrated	Calibrated	
Rm101	1	103	308	92	248	244	348			
Rm102	1	244	326	81	211	215	350	0	0.2	
Rm103	1	180	330	245	212	246	351			
Rm104	1	60	372	231	249	267	358			
Rm105	1	75	370	230	287	252	368	0	0.8	
Rm106	1	80	338	111	216	114	321	0	0.9	
Rm107	1	160	223	167	258	242	353	0	1.3	
Rm108	1	55	172	100	303	273	354	0	0.9	
Rm109	1	55	365	102	352	269	363	0	0.8	
Rm110	1	169	345	92	316	258	351	0	0.5	
Cor111	3	135	201	161	205	236	283	61	64	Influenced by external lighting
		90	170	148	207	162	218	3	4	
		83	208	150		153	212	1	3.8	
C.Rm112	2	193	433	242		285	333	1	3	
		240	382	273		275	354	0	0.8	
Toilet	4	81	206	163		88	263			Influenced by external lighting
		510	146	805		477	648			
		100	564	630		720	150			
		227		638		570	146			
Laundry	2	260	515	288	580	715	723			Influenced by external lighting
		157	692	407	1265	462	603			
Cor116	3	90	190	121	181	145	212	0	2	116 (F) block 1 lamp
		119	192	165		153	213			