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Are There Differences between Estimate (Theoretical) and Actual MACC Approaches of Emission Reduction?

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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 regarding the use of energy are an emerging area of research that has significant implications for policy. Quantitative and qualitative research methodologies were used for this research. 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.' Organisations are planning to use management accounting methods such as Marginal abatement cost curves (MACCs) 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.

Keywords: theoretical MACC approach, actual MACC approach, net present value, theoretical vs. actual energy usage and emission reductions

1. Introduction

1.1 Introduce the Issue

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.

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).

A literature review could be based on literature (MACCs) studies and though of experts, selecting scientific publications is not clear, literature mainly comes from the few years where there were a number of applications of assessment tools in policy and in business where monetary carbon values are used or could be used (Isacs et al., 2016). It can be useful in cost benefit analysis to support the cross-comparison between different impacts and/or with other economic costs and benefits (Harmsen et al., 2019). The other point of view research describes the theoretical and methodological foundations of the two dominant economic approaches for monetizing the impacts of GHG emissions - the cost theoretical approach and the actual approach of MACC - in order to clarify differences when used in decision support tools in both policy and business (Broad et al., 2020; Rafique et al., 2021). Studies also clarify when and why different approaches are applicable and not under different circumstances, which are the most important determinants of the levels of actual and estimated MACC, and uncertainties may be significant (Rafique et al., 2021). This presents examples of existing GHG value estimates that are used and could be used in impact assessment tools within policy and corporate, and a selection of these are applied in a simple case study to explain how the choice of estimate impacts the assessment outcome. Based on this, we discuss and mark some recommendations concerning target principles for choosing a monetary carbon value in different applications and propose future research needs.

1.2 Concerns About Existing MACC Approach

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' environmenta strategies to reduce long-term environmental effects and corporate costs (Epstein, 1996; Broad et al., 2020).

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.

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 & Jouvet, 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.

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 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 question:

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

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, that is more accurate.

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, 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. This research seeks to achieve main objective, namely:

To identify the differences between estimated (theoretical) and actual MACC models at an organisation level.

Little published study 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. 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.

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).

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).

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.

1.3 Net Present Value and Internal Rate of Return

Payback on investments has assessed by company and industry before a decision to implement is made. Process and equipment modifications, which could be implemented by many firms to decrease energy consumption, may 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 can then be rejected. As a result, many businesses 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).

1.4 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.

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 & Jouvet, 2009; Rafique et al., 2021). 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. 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).

2. Study Design and Methodology

To validate the theoretical study, research proposition is developed to answer the research question. Proposition **(P)** 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 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 (**P**) is:

*P***:** *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).

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. Quantifying the cost-effectiveness as 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 1) (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%.

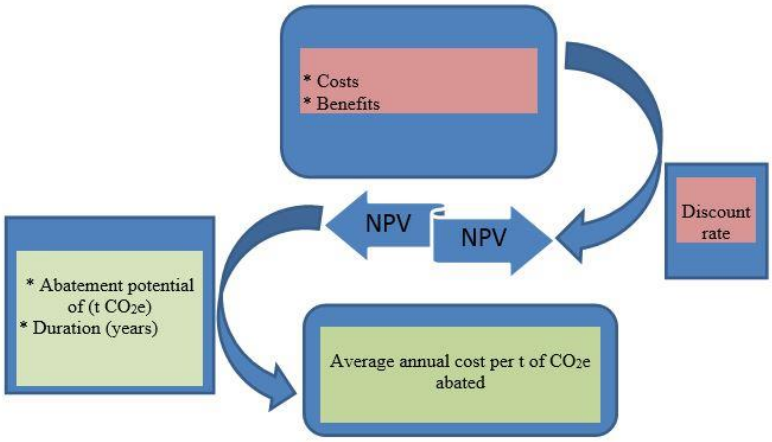

Figure 1. From the economic data of a mitigation action to the marginal cost of the action

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 CO2 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 CO2 = Specific CO2 equivalent mitigation costs;

α * ΔI = annualized capital costs;

ΔB = annual benefits ($);

ΔC = annual costs ($);

ΔMCO2 = annual amount of avoided CO2 equivalent emissions (tonne CO2e).

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 of 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. 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, 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 researches have differences in philosophical foundations, properties, and techniques. These differences show discrimination as a continuum rather than division (Berg, 2004), which make 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; Almihoub et al., 2013). Another structure for collecting and interpreting data is the case study.

2.1 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 in energy savings and emission reductions for being a forward-thinking organisation. Moreover, USQ sustainability reports were examined and verified (EPREO, 2009). USQ has also been identified as a friendly in sustainability commitment by its business partners with 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 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 open policy that helps in sharing information regards 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 save energy directly (technical 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 of actual data of 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 is installed lighting for each building in different kinds of light bulbs (see Appendix 8), and installation of three major meters is to measure energy consumption during periods of specific weeks; each sessions were distributed a survey to provide information about energy and emissions to know the change 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 usage changes of residents residing in Blocks F, I and H. Each distribution was maintained during each rotation (see Appendix 8).

- 1st Rotation F Block (T8's) female occupants 20 days
- 1st Rotation I Block (T8's) male occupants 20 days
- 1st Rotation H block (T8's) female occupants 20 days
- 2nd Rotation F Block (leave in T8's) female occupants 20 days
- 2nd Rotation I Block (change to LED's) male occupants 20 days
- 2nd Rotation H block (change to T5's) female occupants 20 days
- 3rd rotation F Block (leave in T8's) female occupants 20 days
- 3rd rotation I Block (change to T5's) male occupants 20 days
- 3rd rotation H block (change to LED's) female occupants 20 days Data collection and instruments

2.2 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. Eight experts were interviewed and answers were used to develop MACCs.The next section discusses data analysis, quantitative and qualitative, which includes content analysis research.

3. Data Analysis

This study has employed 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.

3.1 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.

3.1.1 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 (2-5) show monthly energy consumption for the years 2009-2012.

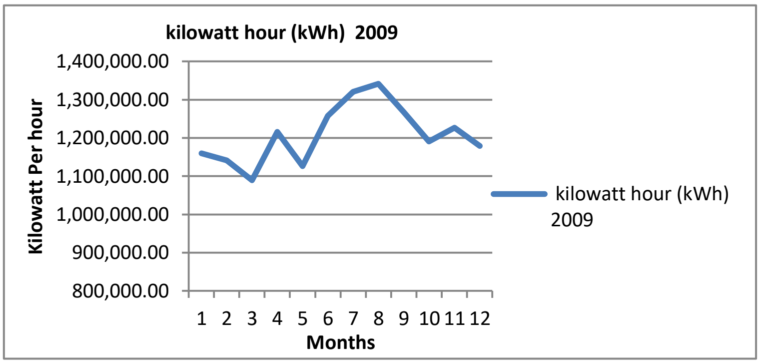

Figure 2. Monthly energy consumption 2009

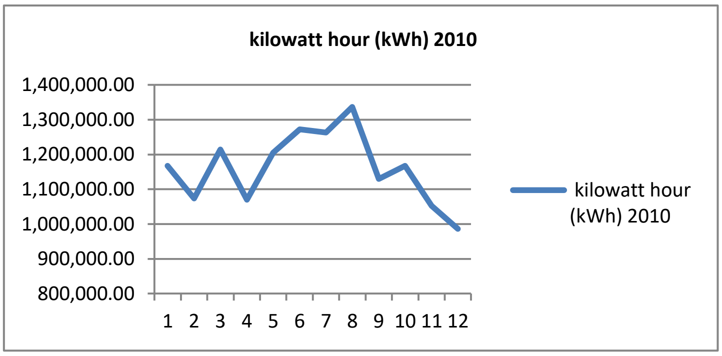

Figure 3. Monthly energy consumption 2010

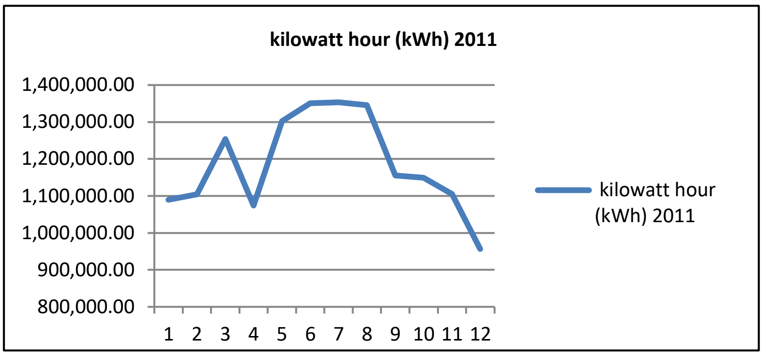

Figure 4. Monthly energy consumption 2011

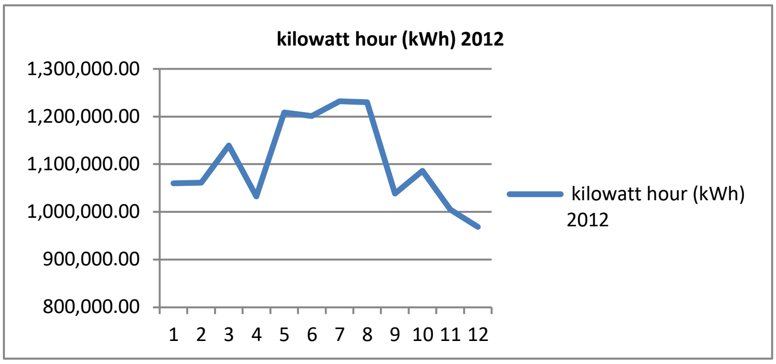

Figure 5. Monthly energy consumption 2012

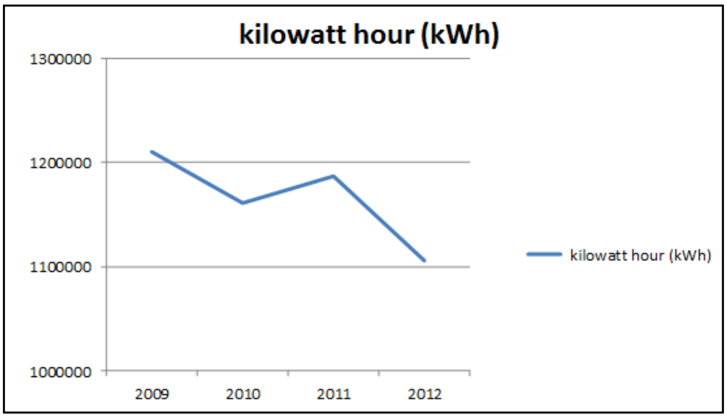

Figure 6. Annual energy consumption 2009-2012

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 2, 3, 4 and 5. The extrapolation process is detailed below in the section data accuracy, as shown in Figure 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.

3.1.2 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 3.6.

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 CO2 saving 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 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 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 8, taking options costs into account. Interesting results from Figure 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.

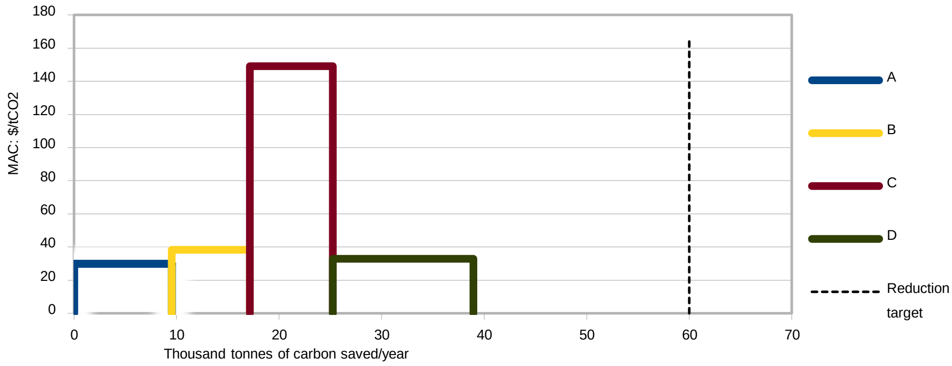

Figure 8. Marginal abatement cost curve USQ Toowoomba campus 2009

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 1 shows emissions relating to energy use; Figure 9 shows comparisons of USQ's emissions from 2009-2012 (Scope 2).

Table 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 CO2e	% of total emissions	Total Tonnes CO2e	% of total emissions	Change Against 2009
Purchased electrcity	13336	80%	12494	79%	13058	77%	12164	73%	-8.79%

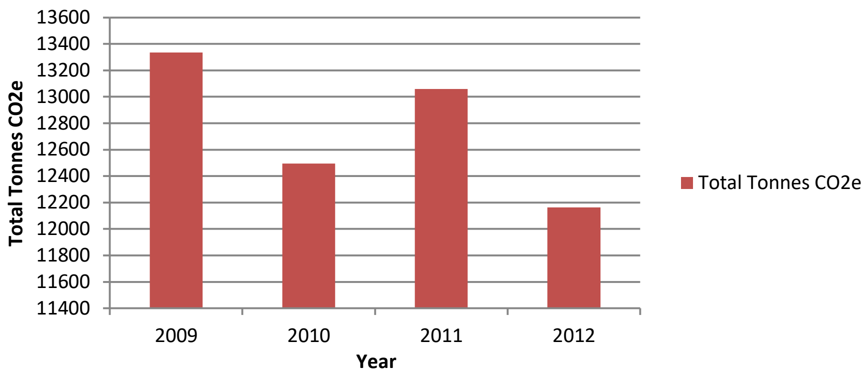

Figure 9. Comparisons USQ emissions 2009 to 2012 scope 2

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 2. Table 1 and Figure 9 illustrate the quantity of the change in emissions over the same period**.**

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

	2009 baseline		2010		2011		2012		% change
Emission source	Total tonnes co2 e	% of total	Total tonnes co2 e	% of total	Total tonnes co2 e	% of total	Total tonnes co2 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%	47.80%
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		

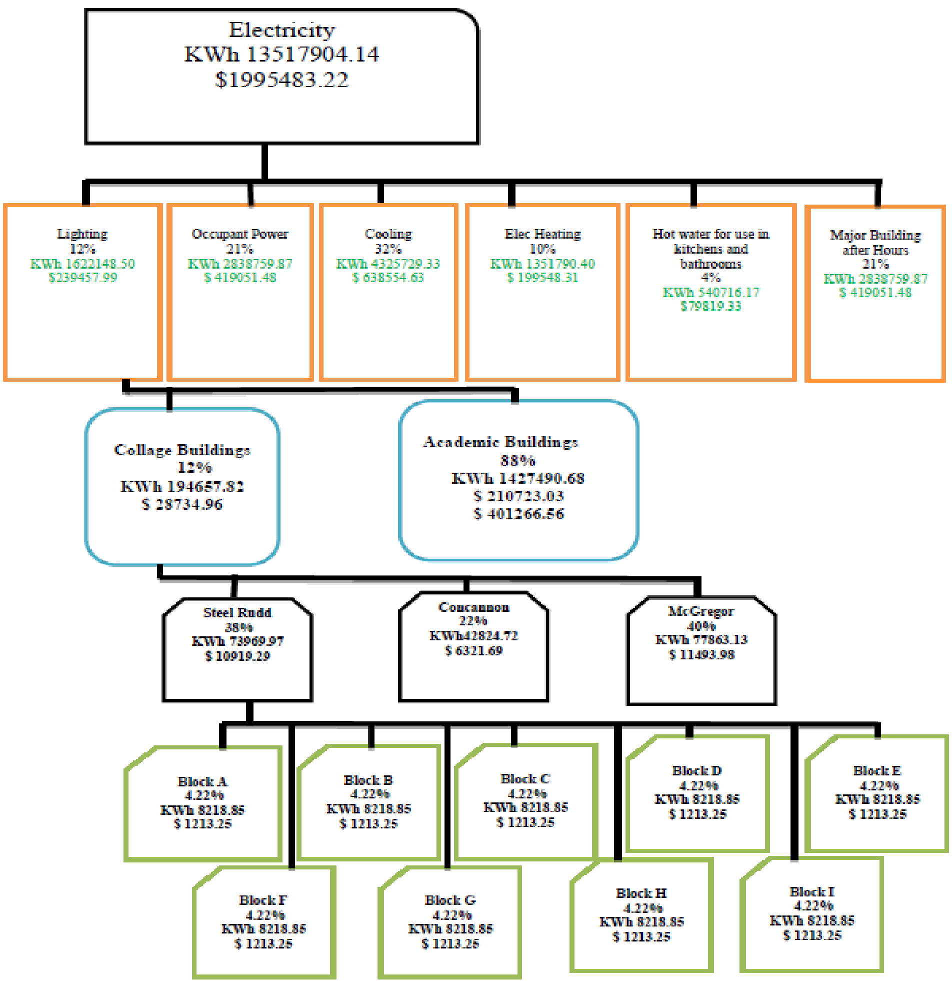

Figure 10. Estimating electricity consumption USQ for 2009

Figure 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 presents theoretical lighting usage (estimating) at Steele Rudd College (USQ). The USQ lighting predominantly uses twin T8 lamps. Figure 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 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.

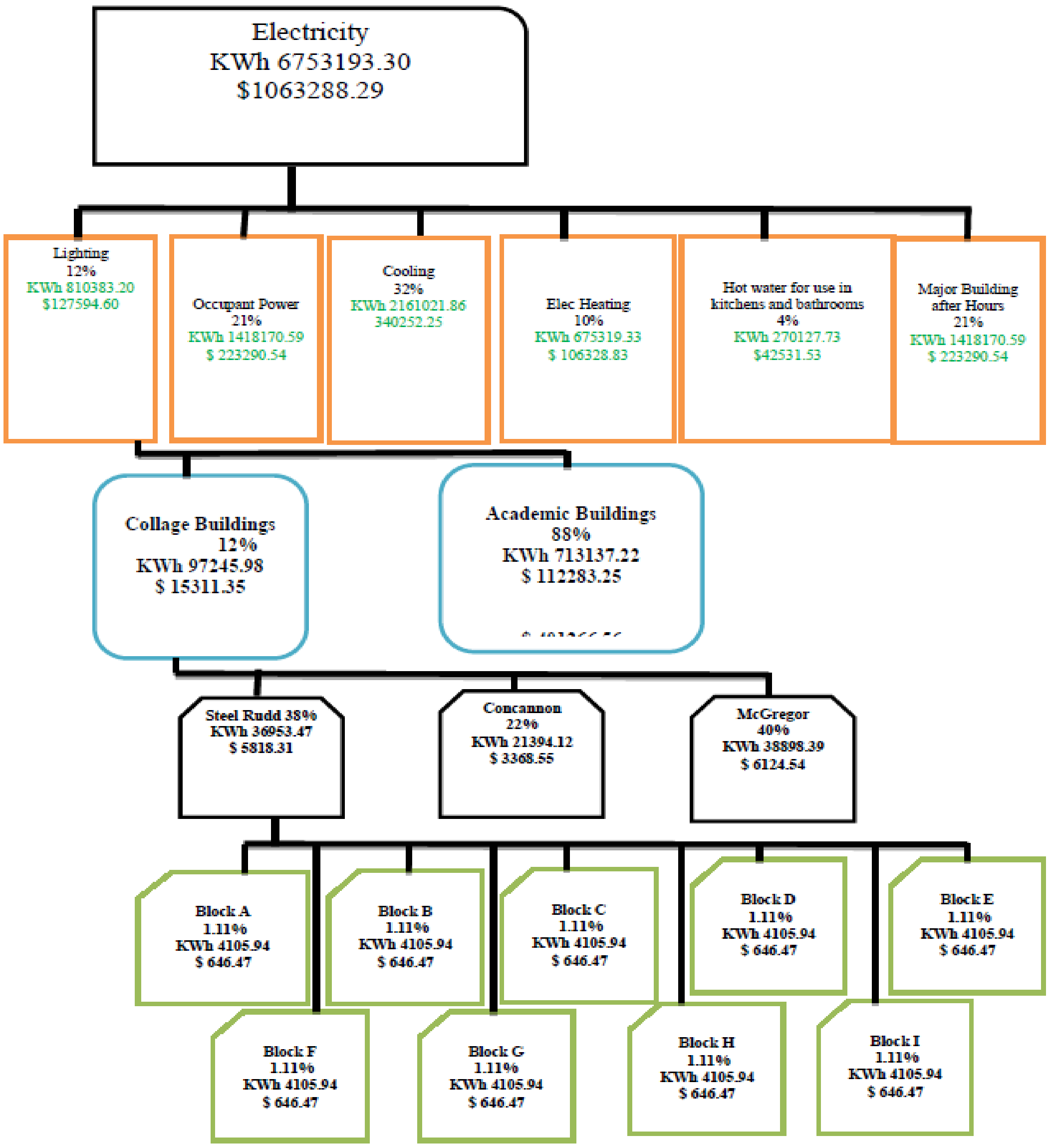

Figure 11. Estimating electricity consumption USQ from January to end of June 2013

Table 3. Project costs and materials

Material	Meter Type	Qty		Cost(exd GST)	Product Life(hrs)	Product Life(yrs)	Notes
Metter	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 for2
T5	24	40	35	1800.00	50.000	15	Adaptor and Tube Cost
LED	11	20	0	579.00	50.000	15	T811=11W
LED	20	0	14	629.00	50.000	15	T820=20W
Labour							
Installation 1st rotation				$1660.00			
Installation 2nd rotation				$635.00			
Installation 3rd rotation				$200.00			

The estimation of lighting usage table 5 is based on figures (10 and 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 4, 5).

Table 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. 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 4 and 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 CO2e. 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 CO2e. 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 CO2e. The cost was $110.58 for Block H.

Tables 5 and 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 CO2e. 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 CO2e. 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 CO2e. The cost was $67.09 for Block H.

Tables 5 and 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 CO2e. 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 CO2e. 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 CO2e. 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 (P) 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.

4. Discussion of Findings

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 9 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; Almihoub et al., 2013).

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.

5. The Contributions

This research has provided important insights; particularly in promoting energy saving and GHG reduction perceptions at firm 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. 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.

6. The Conclusion

This research has analysed 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 the study showed current importance of historical data contributed to providing theoretical MACC. The results in this research also showed that MACC is exhibiting a greater concern in improving corporate environmental performance by increasing information in reports.

To conclude, this study 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 research has also highlighted that the potential for emission reductions are considerable and at less cost.

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