Masters Dissertation

Establishing energy benchmarks for commercial buildings in the City of Cape Town

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Declaration

I know the meaning of plagiarism and declare that all the work in the dissertation, save for that which is properly acknowledged, is my own.

Signed by candidate

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28 June 2011

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Abstract *Establishing energy benchmarks for commercial buildings in the City of Cape Town.*

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Benchmarks are a popular tool for assessing and monitoring energy consumption in existing building stocks worldwide. The South African Government has ambitious aspirations relating to energy efficiency in their commercial building stock, but no clear strategy for tackling existing buildings. This research redresses this by examining international approaches to the benchmarking process and applies these in the context of South Africa. A number of departments within the City of Cape Town municipality collect building related data and it was hypothesised that expensive and time consuming surveys could be avoided by co-ordinating these data. Two types of benchmark were generated using different approaches.

Using a bottom up approach, whole building electricity benchmarks were generated from an initial sample of 422 commercial electricity customers supplied by the City of Cape Town municipality. These data were linked with gross floor area data from the valuation (rates) department, to establish energy intensities. Using a top down approach, benchmarks were developed for a selection of six end-uses, using total energy-consumption data for the commercial sector in Cape Town calculated from Eskom and Municipality billing data. These data were divided amongst individual end-uses by applying standard consumption factors for each end-use. The standard electricity consumption factors were based on estimates for similar USA stocks. Standard consumption factors for other fuels were developed from Cape Town data.

The final benchmarks represent typical (median) electricity energy intensities for retail (241.8kWh/m^2, n=40), offices (176.1kWh/m^2, n=41), business hotels (13.5MWh/bedroom, n=12) and all other commercial buildings (250kWh/m^2, n=20). The end use benchmarks indicated that lighting was the most energy intensive end use. Comparisons with national design targets suggested that they could be more ambitious. Comparisons with similar international building stocks indicated that the Cape Town office benchmarks were comparably low. These benchmarks should be treated with caution due to poor data accessibility and uncertain data quality, which may lead to misleading results. However, in principle this data-collection method and analysis process could be developed to create a state-of-the-art national building energy database for South Africa from existing data.

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Structure of dissertation

This dissertation consists of seven chapters and nine appendices. The appendices contain the detailed calculations that were used to generate the results presented in the main report and are referenced throughout the main report accordingly. The calculations were undertaken using spreadsheets but are presented in a form that the calculations can be followed without a computer. The main report contains the following chapters.

Chapter 1 – Motivation for this study

> *This chapter introduces the topic of energy consumption in buildings and the role of energy benchmarks in improving energy efficiency. A brief discussion of the current energy situation in South Africa leads to a description of the chosen study group and a statement of the objectives of this study and it's limitations. Finally the importance of this study is described in the context of the key stakeholders in South Africa who will benefit from the research.*

Chapter 2 – Introduction to benchmarks

> *This chapter provides a brief overview of the benchmarking process followed by a detailed discussion on each stage of the process including identification of effective data collection and analysis approaches used internationally.*

Chapter 3 – Data Availability

> *This chapter considers the availability of data required to generate energy benchmarks for commercial buildings. It briefly summarises the availability of data internationally and then focuses on South Africa and specifically commercial buildings in Cape Town.*

Chapter 4 – Whole building benchmarks for Cape Town

> *This chapter presents the methodology and results for generating whole building energy benchmarks for commercial buildings in Cape Town.*

Chapters 5 – End use benchmarks for Cape Town

This chapter presents the methodology and results for generating energy benchmarks by end use for commercial buildings in Cape Town.

Chapter 6- Cape Town benchmarks in context

The benchmarks generated in this study are compared with South African design targets to understand the difference between design aspirations and actual energy consumption, and with benchmarks from other countries to understand the performance of Cape Town buildings in a global context.

Chapter 7 – Discussion

Data limitations and data gaps encountered during this study are presented and the extent to which they influenced the outcome of the benchmarking process is discussed. Opportunities have been identified where South Africa can leapfrog traditional data collection techniques. Recommendations have been made for the improvement of the data collection process for Cape Town. Finally conclusions have been drawn in the context of how the benchmarks generated in this study might be used and how they might impact the key stakeholders identified in chapter 1.

1 Motivation for this study

This chapter introduces the topic of energy consumption in buildings and the role of energy benchmarks in improving energy efficiency. A brief discussion of the current energy situation in South Africa leads to a description of the chosen study group and a statement of the objectives of this study and it's limitations. Finally the importance of this study is described in the context of the key stakeholders in South Africa who will benefit from the research.

1.1 General Introduction

As fossil fuel production peaks and the effects of global climate change begin to bite, developing strategies to reduce energy consumption and related greenhouse-gas emissions is becoming increasingly urgent. Improvements in energy efficiency are viewed by many as being the most cost effective and readily implementable approach and have consequently attracted considerable attention globally (e.g. Stern, 2006: xii; International Energy Agency (IEA), 2009: 8; (United Nations Environment Programme Sustainable Buildings and Climate Initiative (UNEP SBCI), 2009a: 2; USA Department of Energy, 2009).

Energy consumed within existing buildings accounts for up to 40% of the annual world energy consumption (IEA, 2010: 37). In the worst case scenario, annual greenhouse gas emissions from buildings are predicted to more than double in the next 20 years based on recent trends (Levine *et al.*, 2007: 392). Although the greatest savings in energy use per building can often be achieved in new buildings, due to the slow turnover of stock, by far the largest overall energy savings are achieved by retrofitting existing buildings (Levine *et al.*, 2007: 389). Improving the understanding of the energy consumed in existing buildings is therefore a high priority for those seeking to reduce our current reliance on fossil fuels (see UNEP SBCI, 2009a).

Despite a number of energy-efficiency programmes in South Africa (Winkler & van Es, 2007: 29, Eskom, 2008a), the introduction of environmental certificates for new buildings (Green Building Council South Africa (GBCSA), 2011) and the effort that has gone into creating national policy and targets (South Africa Department of Minerals & Energy (DME), 2005: 15; South African Bureau of Standards (SABS), 2010), a consistent methodology for monitoring improvements in energy-efficiency in the existing commercial building stock in South Africa is still lacking (DME, 2009: 34; Buch, 2010).

A critical element of implementing any building energy-efficiency strategy in existing building stock, is measuring and monitoring actual energy consumption and setting and meeting targets for improvement. Benchmarks can provide a mechanism for this by defining a value which represents typical building performance against which any building can be compared.

The Green Building Council of South Africa (GBCSA) identified in January 2010 that to be able to develop a version of the South African environmental rating system, GreenStar SA, for existing buildings, they would need to access real energy data for a range of buildings throughout the country (Buch, 2010). This resulted in an invitation, to consultants in February 2011, for proposals to develop an independent building energy benchmarking tool for existing commercial buildings. The energy credit for GreenStar SA for existing buildings would then require a minimum performance to be achieved using the independent energy benchmarking tool. The proposal for the independent tool requires 'national average' benchmarks to be developed from a national database of 'reasonable size and geographical coverage' (GBCSA, 2011).

Most operational energy rating systems that have been developed for use in other countries use benchmarks in the form of annual energy consumption per square meter of either net or gross floor area (kWh/m^2) (Australia Department of Energy Climate Change and Water (Aus DECCW), 2010; Field, 2008; USA Energy Information Administration (USA EIA), 2009). These benchmarks are usually generated from a representative sample of the national building stock, using a bottom up approach to data collection. A bottom-up approach to collecting energy-consumption data in buildings refers to the practice of analysing individual buildings, and then applying this to a larger stock of buildings. This often incorporates a survey technique, the USA Commercial Buildings Energy Consumption Survey (CBECS) (USA EIA, 2009b) is an exemplar of this approach. However, the survey technique is recognised as an expensive and time consuming process, and these are considered to be limiting factors to many countries developing national benchmarks to date (Perez-Lombard, Ortiz, Gonzalez, & Maestre, 2008).

Two operational rating systems recently developed in South Africa, the Energy Barometer (Energy Cybernetics, 2010) and the Enerkey energy certificate (EnerKey, 2011), both avoided the survey approach but use alternative techniques which do not fulfil the GBCSA requirements for a national database of reasonable size and geographical coverage.

In this research an alternative to the data collection by survey technique is investigated, which has the potential to fulfill the GBCSA requirements. Due to the nature of the electricity supply system in South Africa, which enables a large portion of electricity to be supplied by municipalities, South Africa has the opportunity to develop a comprehensive building stock energy database from data that is already collected by the municipalities. By linking the municipality electricity billing data with building data already collected by the South African municipalities for rates calculations, this database could contain energy-related building characteristics for a large portion of buildings in the commercial sector, which could then be used to generate benchmarks.

In this study this potential is explored by linking billing data for a sample of buildings taken from the Cape Town municipality electricity billing database, with building data taken from the Cape Town municipality valuation-database. Further these data are used to generate preliminary energy benchmarks for office and retail buildings in the City of Cape Town and these benchmarks are compared with existing national benchmarks and design targets and international benchmarks for similar building stocks from the UK, USA and Australia (Bannister, 2005b; Field, 2008; USA EIA, 2003).

1.2 Objectives of this study

The aim of this study was to produce energy benchmarks for a variety of building activities within the commercial sector in Cape Town in a time and cost effective manner. It was hypothesised that sufficient existing data was available that could be co-ordinated such that it could be used to generate energy benchmarks for commercial buildings in Cape Town. The notion of using existing data was intended to avoid the costs and time involved in undertaking bespoke surveys (Moffatt, 2004: 6; Perez-Lombard *et al.,* 2008: 274). In order to achieve the aim and test this hypothesis, a review was undertaken to identify successful data collection and analysis approaches used internationally and to identify the availability and quality of data currently collected in South Africa. The intention was to generate benchmarks from a clearly defined sample dataset with well-documented assumptions and access to the original technical references, to allow stakeholders to evaluate the accuracy and applicability of the benchmarks and to understand how the benchmarks could be applied to meet their objectives.

1.2.1 Research questions

In the course of testing this hypothesis the following research questions were considered:

- Does the available data represent the commercial building stock in Cape Town?
- How far off is the annual energy consumption of existing commercial buildings in Cape Town from recently proposed design standards required for new buildings.
- How do Cape Town's commercial buildings perform in terms of energy consumption relative to other countries?
- Are there any opportunities for South Africa to leap frog other countries in terms of data collection for generating national benchmarks?

1.3 Limitations of this study

1.3.1 Energy used in operation

This dissertation concentrates on energy used in buildings during their operation. It does not consider energy predictions made for a base building at design or construction stage and it does not cover embodied energy used to form materials, or energy used during construction and demolition.

1.3.2 Data collection

This research considers the coordination of existing data collection mechanisms and as such does not include the collection of raw data from surveying or modelling individual buildings.

1.4 Value of this study

In order to determine the value of this study the primary project stakeholders were identified. These were defined as groups or organisations that would directly benefit from the research. The background to each stakeholder and their link with the research and the criteria for this study to be useful to each stakeholder are presented here.

1.4.1 The Department of Energy of South Africa

The government department responsible for energy policy in South Africa is the Department of Energy, formerly the Department of Minerals and Energy (DME). The South African national energy-efficiency strategy set a national target of 15% energy-efficiency improvement for the commercial and public building sectors by 2015 (DME, 2005: 15). The strategy stated that the DME had embarked upon a programme to develop detailed methodologies for monitoring and tracking of sectoral targets (DME, 2005: 17). However these methodologies have yet to transpire, further fuelling the perception that there is a discrepancy between intent and action in South Africa relating to energy-efficiency policy in buildings (Winkler & van Es, 2007: 37; Construction Industry Development Board (CIDB), 2009: 2).

This perception is further exacerbated in the latest review of the national energy-efficiency strategy, which suggests that, to date, only two mechanisms for improving energy efficiency in buildings have been introduced as a consequence of the energy-efficiency strategy (DME, 2009: 42). Further, despite new buildings in South Africa contributing to only ~ 2.7% of the total commercial building stock floor area in 2007 (see Appendix 4: Floor area estimate), both these mechanisms were aimed at buildings at design stage and not at existing buildings in operation (see GBCSA, 2011; SABS, 2010).

For this study to be useful to the Department of Energy the research must focus on existing buildings. The study benchmarks must be able to demonstrate how an existing typical commercial building compares with the proposed national design targets for new buildings (SABS, 2010: 7) and how this relates to the 15% national energy efficiency target (DME, 2005: 15).

Furthermore, the benchmarking process presented in the form of energy certificates is becoming a popular policy tool internationally for enforcing energy-efficiency in buildings (e.g. Energy Performance of Buildings Directive (EPBD), 2005; Australian Department of Energy, Climate Change & Water (Aus DECCW), 2010). The study must provide information to understand the feasibility of developing and implementing a national benchmarking process for South Africa on which an operational energy performance certificate could be based.

1.4.2 National Energy Efficiency Agency

The National Energy Efficiency Agency (NEEA) was established by the Government in 2006. The NEEA key objectives, amongst other things, were to "co-operate with persons, associations and institutions undertaking energy efficiency programmes in other countries, to ensure that international 'best practices' are adopted and applied in South Africa" (Eskom, 2008a: 15).

For this study to be useful to the NEEA, it must provide a summary of international 'best practice' relating to the energy benchmarking process for the commercial building sector.

1.4.3 The City of Cape Town Municipality

The City of Cape Town has shown an active interest in energy-efficiency and the environment for a number of years (City of Cape Town (CCT), 2011). The City's first State of Energy report was published in 2003, which included a baseline year of energy consumption for the City disaggregated by sector and by fuel (SEA, 2003a). Since then the City has published a number of reports that have been concerned with energy efficiency as well as the environment as a whole (SEA, 2003b; Winkler *et al.,* 2005; Fedorsky, Borchers, & Dobbins, 2006; Palmer Development Group (PDG), 2007; CCT, 2008; CCT, 2009a). The City of Cape Town is in the process of developing the Cape Town Energy and Climate Action Plan (ECAP), which was adopted by the Council in May 2010.

For this study to be useful to the municipality it must provide a well documented estimation of commercial energy consumption in Cape Town. This can then be used for future forecasting of energy consumption to guide policy decision making.

1.4.4 Eskom

Eskom is the state owned national electricity provider in South Africa. Many of the energy-efficiency programmes introduced in the commercial sector in South Africa in the last few years were prompted by short-term national electricity demand issues. These demand issues took the form of rolling blackouts in the Western Cape in the summer of 2005/2006, caused by technical problems at the Koeberg Nuclear power station (Eskom, 2006) and nationwide blackouts in the summer of 2007/2008, caused by lack of sufficient energy generation to meet the growing national demand (Eskom, 2008b). Even if the current build programme for new power stations goes ahead with no delays, an energy crisis is still being predicted for South Africa in 2012 and rolling blackouts are anticipated from 2011 through to 2016 (Medium Term Risk Mitigation (MTRM) Project Team, 2010).

In response to these electricity-generation issues, Eskom began a programme of expanding supply options where possible and also focussed heavily on promoting energy efficiency through demand side management (DSM) (Eskom, 2008a). Eskom's DSM strategy comprised a dual approach: to reduce electricity demand at peak periods by shifting loads to off-peak periods and to reduce overall electricity consumption by installing energy efficient equipment and optimising industrial processes. The energy efficiency DSM programme provides funding for approved energy efficiency project proposals submitted by registered Energy Services Companies (ESCo). The ESCo is responsible for implementing the energy efficiency project and are paid in full for their services only after the proposed savings have been achieved. A number of independent Measuring & Verification (M&V) teams (Universities) were created to provide all the stakeholders with an impartial quantification of the savings achieved.

Results of this study must support the Eskom energy efficiency DSM initiative and provide information that can assist Eskom in targeting their DSM programmes to areas that will realise the greatest benefit.

1.4.5 Green Building Council of South Africa (GBCSA)

Environmental labelling has been addressed in South Africa by the recently formed Green Building Council of South Africa (GBCSA). Launched in 2007, the GBCSA, supported by the GBC of Australia, made their first priority adapting the Australian GreenStar environmental auditing tool for offices to apply to South Africa. This was formally launched in 2008 and was followed in 2009 by the launch of the GreenStar tool for retail. The current tools apply to a base building at design or construction stage and not a building in operation.

The GBCSA identified in January 2010 that to be able to develop a version of GreenStar SA for existing buildings, they would need to access real energy data for a range of buildings throughout the country (Buch, 2010). This resulted in an invitation, to consultants in February 2011, for proposals to develop an independent building energy and water benchmarking tool for existing commercial buildings. The energy credit for GreenStar SA for existing buildings would then require a minimum performance to be achieved using the independent water/energy benchmarking tool.

The proposal for the independent tool requires 'national average' benchmarks to be developed from a national database of reasonable size and geographical coverage and normalised by climate (GBCSA, 2011).

For this study to be useful to the GBCSA the research must identify a data collection process that fulfills the GBCSA requirements for a national database of reasonable size and geographical coverage.

1.4.6 Building owners and operators

The most common use of energy benchmarks, for commercial buildings in the UK and USA in particular, has been by energy managers. Energy managers often use benchmarks to monitor progress and identify actions to improve energy efficiency as part of an energy-management strategy. Benchmarks allow energy managers to understand and manage their buildings better by assessing how efficiently their buildings use energy relative to similar buildings nationwide. Furthermore, in a commercial environment, being able to demonstrate that a building is operated more efficiently than that of a competitor, can be of considerable marketing value due to an increasingly environmentally aware customer base.

A number of South African businesses and institutions have already embarked on voluntary energy audits to reduce their energy consumption. For example Woolworths retail group and Nedbank, are examples of commercial businesses that have voluntarily created environmental strategies for their businesses including energy efficiency targets (Woolworths Holdings Ltd, 2009; Cheeseman, 2010).

A recent awareness of energy efficiency was made particularly apparent in the commercial buildings sector in Cape Town, with the launch, in 2007, of the energy-efficiency forum for commercial buildings (CCT, 2009b). This was the first South African city-level public-private partnership created to promote electrical energy efficiency in commercial buildings. Stakeholders in the Cape Town region meet regularly to share knowledge on energy efficiency measures they can make to their buildings. The forum focuses on knowledge sharing in the area of implementing energy efficiency programmes and interventions, and encourages participants to measure and monitor their buildings energy performance and create strategies to improve their energy efficiency. Currently these businesses only have their own building stock or data from previous years to compare their progress against.

For this study to be useful to building operators and owners in South Africa, it must generate whole building and end use benchmarks from a clearly defined sample dataset of South African buildings, with well-documented assumptions and access to the original technical references. This will allow operators and owners to evaluate the accuracy and applicability of the benchmarks to their building. The final benchmarks must be as detailed as possible in terms of considering energy consumption for end uses (e.g. heating, cooling, lighting etc). This will allow operators to identify areas in their buildings, which are under performing compared to a similar typical building, and determine the systems which will benefit the most from energy efficiency measures.

1.4.7 Building designers and consultants

Engineers can use operational energy benchmark data during very early stages of design, to estimate energy consumption of the future building inclusive of occupant behaviour. This assists in selecting the most appropriate technical solutions to meet energy and cost targets set within the design brief or by legislation. Operational energy consumption often varies from estimates made using computer simulation and understanding a country's existing buildings energy-consumption can provide designers with valuable insights into how buildings are run in actuality.

For this study to be useful to building designers and consultants it is again important that the benchmarks have well-documented assumptions and access to the original technical references so that designers can evaluate their relevance. The final benchmarks must be as detailed as possible in terms of considering energy consumption for end uses so that the influence of different systems on energy consumption can be understood.

2 Introduction to benchmarks

This chapter provides a brief overview of benchmarks and the benchmark process, followed by a detailed discussion on each stage of the process including identification of effective data collection techniques and analysis approaches used internationally.

2.1 The benchmark process

An energy benchmark provides a reference level of energy consumption for a given building activity, against which other buildings can be compared. When related to energy performance in buildings, the benchmark is often the median energy intensity representing typical practice in an existing population (e.g. Field, 2008). Benchmarks can also be presented as good practice benchmarks, these are based on identifying the energy intensity of the top quartile in an existing population of buildings (e.g. Jones, 2004: 13.3). Benchmarks are different to targets, which provide a minimum aspirational value (e.g. SABS, 2010: 7), however benchmarks are often used to develop targets.

The use of energy benchmarks in the commercial building sector is often described as a process that involves four stages (Matson & Piette, 2005: 1; Perez-Lombard *et al.,* 2008: fig 2). These involve data collection, data analysis, a comparison analysis, and finally recommendations for improvements based on the outcome of the comparison analysis (Table 1).

Table 1: The key stages in the energy benchmarking process.

1. External data collection	2. Internal data collection	3. Comparison Analysis	4. Improvements
Collect annual energy performance data for a sample of existing buildings.	Collect annual energy performance data for the building under review.	Generate a benchmark from external data. Compare with internal data for building under review.	Identify elements where energy savings can be made.

2.2 Data requirements

A statistically representative sample of buildings is required to generate benchmarks for a building stock (UNEP SBCI, 2009b: 8 &15). This involves collecting data for a random selection of buildings with a variety of characteristics (such as size and location), within the population under consideration. The greater the variety in the population, the greater the sample size required to obtain a representative sample.

For each building in the sample, there are a number of characteristics that are critical for generating energy benchmarks (Table 2). Further characteristics are useful in understanding the composition of the building stock when considering energy-efficiency measures, but are not required for the generation of benchmarks. These include floor to ceiling heights, collected to allow predictions of energy savings relating to improvements in wall insulation in the national building stock to be made (e.g. University College London (UCL), 2001); a measure of indoor environmental quality (internal comfort), collected to include a measure of service provision by the building (see Roulet *et al.*, 2002; Perez-Lombard *et al*., 2008: 276); and details on the technologies installed in the building stock (e.g. percentage of floor area air conditioned, type of heating/cooling system) to allow for a greater understanding of energy drivers in the building stock in question (e.g. USA Energy Information Administration (USA EIA), 2003: Tables A1to B46).

Table 2: Data requirements necessary for generating energy benchmarks

Data to be collected	Description
Energy Data	Annual whole building actual energy data collected by fuel source. Usually taken from billing data or energy meters.
Gross floor area	This is the most common energy-intensity indicator for commercial buildings.
Principal building activity	Due to the diverse nature of activities undertaken in commercial buildings it is useful to group similar building activities to allow more specific benchmarks.
Geographical location	Knowledge of each building's location in the sample allows appropriate degree days to be calculated so that benchmarks can be adjusted to account for variations in external air temperature between locations and years.
Occupational details	Occupational details (such as occupancy hours, number of computers etc.), allow adjustments to be a made to the benchmarks to allow for variations in occupational details outside the control of the building operator.
Energy consumption by end use	An understanding of the proportion of energy consumed by each end use (e.g. heating, cooling, lighting etc) allows adjustments to the benchmarks that only relate to a particular end use to be made more accurately. Furthermore generating benchmarks that consider end uses allows problematic areas of energy consumption to be easily identified and recommendations for improvements to be more specific.

2.3 Standard metrics for benchmarks

Benchmarks are usually presented in the form of energy intensities. The energy intensity is the ratio between energy consumption and an indicator of physical activity (e.g. floor area, number of occupants, number of rooms etc). The indicator of physical activity can be termed the energy-intensity indicator, energy use indicator or energy-performance indicator.

Often energy use is presented in terms of greenhouse gas emissions, due to global concerns relating to the connection between the use of fossil fuels and climate change, in this case they are presented in the form of carbon intensities. Benchmarks can be published as energy intensities and converted to carbon intensity during the comparison analysis (e.g. Field, 2008: 1). This allows for carbon factors to change annually with differing fuel mixes without impacting the initial energy benchmark database.

Guidelines developed by the United Nations on measuring energy use and reporting greenhouse gas emissions from building operations, emphasize that it is critical that newly forming national and international data collections adopt the same metrics, so that data can be compared easily across the world (UNEP SBCI, 2009b: 9). The metrics recommended for measuring energy and carbon consumption from building operations are:

- Energy Intensity = $kWh/m^2/year$ (kilowatt hours per square meter per year)
- Carbon Intensity= $kgCO_2e/m^2/year$ (kilograms of carbon dioxide equivalent per square meter per year)

In the above metrics the energy-intensity indicator is the gross floor area, defined as the floor area measured from the outside face of external walls (UNEP SBCI, 2009b: 9).

2.3.1 Energy *intensity* or Energy efficiency?

Energy intensity refers to the energy used per unit of output and is the most commonly used basis for measuring trends in energy efficiency in buildings. Energy intensity is generally assumed to be inversely proportional to energy efficiency, e.g. as energy intensity declines, energy efficiency improves (U.S. Department of Energy, 2008). The term energy-efficiency is usually used in the context of buildings to express achieving the same or better performance (in terms of a service) using less energy. This implies that to measure energy efficiency, a ratio of energy input to service output should be measured. The metric used to indicate energy efficiency should therefore include a measure of energy consumption and an indicator of service e.g. lighting efficiency can be expressed in $W.m^2/100$ lux (energy intensity per light output) and specific fan power is expressed in W/(l/s) (energy consumed per flow rate of air). For buildings, this is more difficult as a building provides many services (e.g. light levels, air temperature, ventilation rates, adequate floor area).

The most common energy-intensity indicator used to compare a building is the floor area as many services also correlate with floor area. However this does not indicate whether certain minimum standards in service provision have been met. This potentially allows buildings that use less energy due to poor service provision to be rewarded for achieving a lower energy intensity.

For policy makers considering mandating energy certificates for existing buildings, addressing this issue has been acknowledged as being a complex task (Perez-Lombard *et al.,* 2008: 276). Environmental certificates generally avoid this issue, as they consider wider issues than just energy consumption and usually incorporate a requirement for a certain standard to be achieved in the internal environment to qualify for certain ratings. However, for energy certificates and rating systems, including a measure of service output is less common and most certificates do not include any measure of service provision.

2.3.2 Gross or Net floor area?

Where floor area is chosen as the energy-intensity indicator, its value is as important in determining the final result as the energy figure. It is therefore critical that, when comparing energy intensities, the same floor area metric is used. In South Africa the gross floor area (construction floor area), is defined as the sum of the areas measured at each floor level over any external walls to the external finished surface (Brummer, 2009: 58). This definition follows the United Nations definition (UNEP SBCI, 2009b: 9).

However, the UK uses gross internal floor area as its energy indicator metric, measured from the internal surface of external walls. The UK benchmark publication provides standard conversion factors to convert secondary metrics which might be more readily available than gross floor area (e.g. net lettable area for offices and sales floor area for retail) (Field, 2008).

In South Africa net area can mean rentable (lettable) area or useable area. Rentable area is the total internal area of a building adjusted by deducting major vertical penetrations (excluding columns). It includes all rentable area, common areas and parking. Useable area is as rentable area, but excludes common areas and parking (Brummer, 2009: 58).

Australia changed from gross floor area to net lettable area (NLA) for their energy rating scheme (then the ABGR) after a year of operation (Bannister, 2005b: 40). This was at the request of industry on the grounds that NLA was the standard production variable in the industry and that using gross floor area rewarded buildings with large unconditioned, unoccupied areas, because they had lower energy intensities. The Australian view is that benchmarks should always be based on NLA to avoid rewarding spatially inefficient buildings. However this is contrary to United nations recommendations for a common carbon metric, which is based on gross floor area.

2.3.3 Useful or final energy?

The terminology used to describe energy consumption can be confusing, especially as different countries use different terminology (Table 3). Useful energy is generally used as the energy consumption metric for energy consumption in buildings as it is easier to measure. Useful energy is defined as the energy supplied to a building in the form of gas, heat or electricity. Unlike final energy, useful energy does not take into account the losses incurred before the energy reaches the building. Final energy differs from building to building but is usually calculated using average national conversion factors (USA Environmental Protection Agency (USA EPA), 2010: 5).

Table 3: Terminology for energy consumption in UK, USA and RSA

RSA	**USA**	**UK**	Definition
Useful energy	Site energy	Delivered energy	The energy product created from raw fuel, usually supplied to a building in the form of gas, heat or electricity, this is the value found on energy bills. Useful energy does not take into account the losses incurred before the energy reaches the building
Final energy	Source energy	Primary energy	Useful energy plus energy used during transmission, delivery and production. The transmission, delivery and production losses will vary from fuel to fuel and from building to building.

2.4 Data collection

Energy benchmarks can be generated from either measured energy data or by simulating energy consumption using computer models. The appropriate method depends upon whether the influence of occupants is to be considered. When this is the case, benchmarks are generally generated from measured data for a representative sample of the national building stock (e.g. Field, 2008: 1; UNEP SBCI, 2009b: 8; Bird, 2010; USA Environmental Protection Agency (USA EPA), 2010: 2).

Computer simulation is generally not used to generate operational benchmarks because substantial discrepancies exist between simulated performance and measured performance (Bannister, 2005: 35). The reasons given for the discrepancies include natural uncertainties such as weather data, as well as assumptions relating to occupant behaviour (Perez-Lombard *et al.,* 2008: 274). Despite this, computer simulations have been used to fill data gaps in measured data such as estimating the portion of energy used for specific end uses within buildings (e.g. USA EIA, 2009a). Problems with discrepancies between measured and simulated values were avoided in this instance because only the relative share of energy consumption was required.

A number of guidelines are available for collecting energy or greenhouse gas emissions data from individual buildings in operation (see Field, 2006; American Society of Heating Refrigeration & Air-conditioning Engineers (ASHRAE), 2007; Efficiency Valuation Organisation (EVO), 2009). These were mostly developed for undertaking detailed energy audits on individual buildings and include methods for measuring or estimating energy consumption for particular end uses. Guidance is also available for collecting energy-performance data for a representative sample of the national building stock, including descriptions of methods and barriers to collecting data and how the data might be used (see Moffatt, 2004).

A bottom up approach to data collection in buildings in operation is described in the common carbon metric (CCM) (UNEP SBCI, 2009b: 8 &15). The approach requires collecting data in a measurable, reportable, and verifiable (MRV) manner for a statistically representative sample of building types. The CCM suggests that these data may be readily available through utility and fuel providers. If measurable statistical sampling is not possible or feasible the CCM allows average or generic data to be used if it is representative of the local technologies, construction and building types.

Despite these guidelines having been developed a number of years ago, a review of international benchmark databases showed that few countries have undertaken the task of generating national benchmarks from operational data to date (Perez-Lombard *et al.* 2008: 274). Notable exceptions were the USA (USA EIA, 2009b), the UK (Field, 2008)and Australia (Bannister, 2005).

The methods for collecting energy data on the building under review is often very similar to the method used to collect energy data on the buildings in the sample. Despite this, most operational rating systems generate benchmarks from a representative sample of the national building stock and do not use the data collected from the buildings under review to generate the benchmarks (e.g. Field, 2008; Bird, 2010; EPA, 2010: 5). This allows the rating systems to be used to monitor improvements based on comparison against a constant benchmark.

2.4.1 USA data collection

The USA developed the commercial buildings energy-consumption survey (CBECS) in 1979.

CBECS is a national sample survey carried out every four years that collects information on a statistically representative sample of U.S. commercial buildings, including their energy related building characteristics, their energy consumption and energy expenditures. The most recent published data was from the 2003 survey which included 5215 buildings (USA EIA, 2009c). The interviews took 226 staff, six months to undertake. The data from the most recent survey, undertaken in 2007, has yet to be published. Canada conducted a similar survey in 2001, the commercial and Institutional Building Energy Use Survey (CIBEUS) (Government of Canada, 2010). Although the USA has a comprehensive and accessible national database, it does not publish benchmarks as such.

2.4.2 UK data collection

The UK publish a comprehensive list of benchmarks for different building activities but do not provide any details of the datasets from which the benchmarks were generated. The most current UK energy benchmarks for commercial buildings were published in a document commonly referred to as TM46 (Field, 2008). These benchmarks were based on data from surveys undertaken in the 1990's and were first published as a single comprehensive database in 2004 (Jones, 2004). There are no details published of the sample sizes or data collection and analysis techniques used to develop these UK benchmarks. This potentially limits the applicability of the benchmarks as it is not clear whether the samples truly represent the national building stock.

2.4.3 Australian data collection

In Australia, a national database of 215 office buildings was developed in 1989 for the Australian Building Greenhouse Rating (ABGR) launched nationally in 2000 (Bannister, 2005). The ABGR was incorporated into the National Australian Built Environment Rating System (NABERS) in 2008 and is now known as NABERS energy (Aus DECCW, 2010). NABERS energy is currently available for offices, hotels and shopping centres. However, there is no published data on the samples used as the basis for the benchmarks used in the current rating system. NABERS instead publish a 100 page protocol to registered assessors that specifies the characteristics of buildings that can be reviewed using the rating system. These characteristics are derived from the bias of the samples. For example NABERS energy for hotels is only applicable to large business hotels as these are the only types of hotels covered in the initial sample.

2.4.4 South African data collection

In South Africa two operational labelling systems have been recently developed and neither of these systems have generated benchmarks from a national dataset using the survey technique. The energy barometer certificate (Energy Cybernetics, 2010) avoided the issue of developing a national dataset, by using information from the other buildings assessed using the labelling scheme in the previous year. This approach allows participants to track their progress on a year to year basis with regard to the industry average, i.e. if the industry average improves but the building does not, this is recognised with this approach. However it does not allow buildings to be compared against each other, if they have ratings calculated in different years, and it does not provide a representational sample of national building stock. The EnerKey energy certificate (EnerKey, 2011) compared operational energy consumption against the design targets published in the draft building regulations calculated by computer simulation (SABS, 2010: 7). Literature suggests that this is not good practice because of the substantial discrepancies observed between simulated performance and measured performance (Bannister, 2005: 35).

2.4.5 Building activities included in the commercial sector

Due to the wide variety of activities undertaken within the commercial sector, benchmarks are usually generated for a number of different sub-sectors based on the activity being undertaken in the building. This allows the benchmarks to be more specific and potentially more accurate.

The decision of how many categories to include and which buildings fall into which categories is not formalised in the energy sector. The UK has published benchmarks for twenty-nine different non-domestic building activities that encompass all buildings that are not residential (Field, 2008), the USA benchmarks include fourteen commercial building activity categories that encompass all buildings in which commercial activities are undertaken on 50% of the floor area or more (USA EIA, 2009d). Economists formalise building activity sub-sectors more rigorously than energy professionals. In the USA a Standard Industrial Classification (SIC) system was developed in 1937 in an attempt to classify all forms of economic activity in order to provide a common statistical and conceptual framework for data collection and analysis. This system was superseded in 1997 by the North American Industry Classification System, (NAICS) (US Census Bureau, 1997). This system is used by the USA CBECS to define the buildings included in each category (USA EIA, 2009e).

In South Africa, economic data is collected by Statistics South Africa (Stats SA) under the SIC categories. However, building data collected by Stats SA is not related to the SIC or NAICS categories. Stats SA collect data on the floor area of non-domestic buildings completed each quarter under the six categories of (1) shopping; (2) office and banking; (3) industry, warehouse and workshops; (4) schools, crèches, hospitals and clinics; (5) churches, sport and recreation; (6) other (Stats SA, 2009). Rather strangely the Stats SA questionnaire includes tourist accommodation and casinos in the residential sector, these would more usually be included in commercial sector. This highlights the importance of standardising the definition of the commercial sector. Although Stats SA use six categories to collect non-domestic building data, they only published data for the four categories of (1) shopping; (2) office and banking; (3) industry, warehouse and workshops; (4) other (Stats SA, 2010).

Most reports published in South Africa do not disaggregate energy data further than the primary economic sectors of industry, residential, commercial, public sector, agriculture and transport. An exception to this is the 2002 greenhouse gas inventory for South Africa, which sub-divides the commercial sector into eight categories (DeVilliers, 2000).

2.5 Comparison analysis

The comparative analysis is regarded as the core of the benchmarking process (Perez-Lombard *et al.*, 2008: 275). The output of the comparison analysis when considering a building in operation is often termed the 'operational energy rating'. The term 'energy rating' is used frequently in the context of the energy benchmarking process and refers to the ranking of a building, based on a comparative assessment of its energy performance. An energy rating represents comparative energy consumed over a period of 12 months in relation to the benchmark and not actual units of energy consumed. A number of specific methodologies have been developed to undertake the comparison analysis of the benchmark process, and these are invariably referred to as 'energy rating systems'.

The development of an energy rating system requires an analysis of the sample data, to identify key characteristics that influence energy-consumption outside the control of the building operator (e.g. floor area, outside temperature, hours of use, etc). From this analysis, factors can be developed to adjust the benchmark so that the typical characteristics of the sample are normalised to those of the building under review. Characteristics such as building services design and operation profiles are not included in this process, this means that buildings with systems and operation strategies that are less efficient than typical can be identified as using more energy.

The most common characteristics to be considered in the normalisation process are variations in outside air temperature for different locations and years, often referred to as weather or climate adjustments, and variations in hours of occupancy (e.g. Field, 2008: 2; UNEP SBCI, 2009b: 8; EPA, 2010: 5). Some energy rating systems identify additional characteristics specific to different building activities through statistical modelling, such as number of PCs for offices (e.g. Bird, 2010; USA EPA, 2010: 8).

Weather variations are the most complex of the characteristics that influence energy-consumption. Studies have determined that temperature is the most influential weather characteristic on energy consumption in buildings (USA EPA, 2010: 9). The accepted method of adjusting for variations in temperature between years and locations is by using degree days (Field, 2008: 13; UNEP SBCI, 2009b: 8; USA EPA, 2010: 9). Degree days are a simplified form of historical outside air temperature. Heating degree-days are a measure of how much (in degrees), and for how long (in days) the outside air temperature is below a base temperature. Cooling degree-days are a measure of how much, and for how long the outside air temperature is above a base temperature. The base temperature represents a typical value of outside temperature at which the heating or cooling system is likely to be switched on. Energy consumption for heating and cooling a building tends to be dependent on outside air temperature. Weather correction (or normalisation) therefore allows energy consumption for heating and cooling for buildings from different years or locations to be adjusted to factor out any differences in outside air temperature.

The normalisation process is followed by the development of a rating system to compare the building under review against the adjusted benchmark, this can be in the form of software algorithms or a simple percentage improvement over the benchmark.

2.5.1 Normalisation process

The process of calculating the adjustment factors necessary to generate normalised benchmarks has been approached in two ways. When sufficient data is available, statistical regression analysis can be used to develop an adjustment equation (e.g. USA EPA, 2010: 5). The regression analysis approximates the average relationship between the characteristics and energy intensity across the initial sample. With this approach, the adjustment factors take the form of average values of energy intensity per unit increase in the building characteristic e.g. mean kilowatt hours per square meter, per heating degree day.

When insufficient data on characteristics is available in the sample, adjustment factors can be estimated by assuming a relationship between average energy intensity of the sample and a reference building characteristic representative of the sample, but calculated from external sources, rather than using characteristic data from the actual sample (e.g. Field, 2008). With this approach the adjustment factors take the form of a ratio that scales the portion of energy influenced by the characteristic.

Using the adjustment factors calculated by either of the above methods, and the characteristics of the building under review, an adjusted benchmark can be calculated against which the building under review can be compared.

2.5.2 The energy rating system

Following the statistical analysis and development of adjustment factors, an energy rating system is developed, often in the form of an algorithm which can be used by software, to compare the energy intensity of the building under review (actual energy intensity) against the adjusted benchmarks.

In most cases the energy rating process or algorithm calculates the ratio of actual energy intensity to adjusted benchmark and presents this as a rating. A rating of one would correspond to the typical energy intensity of the represented building stock. This ratio is sometimes termed the energy-efficiency ratio (USA EPA, 2010:12).

Energy labeling is a method of presenting the energy rating of a building in a visual form. Energy labeling requires the development of a scale related to the energy rating that then provides classes into which the building's energy rating can be categorised (Perez-Lombard *et al.,* 2008: 276). The scale can be either linear (e.g. United Kingdom Department for Communities and Local Government (UK DCLG), 2007) or non linear (e.g. EPA, 2010). The scales can vary considerably between schemes (Table 4).

Energy certificates are a progression on from labels, they present all the stages of the benchmark process including the final stage – improvements. A review of energy certificates in operation around the world showed that they all had certain elements in common (Table 4). Generally they all displayed an energy label in a graphical and easy to read format. Most certificates also provided sufficient information about the building under review to be able to compare buildings of a similar type and most certificates also included a mechanism to inform building users and owners where energy savings could be made, usually in the form of an accompanying report (see section 2.5). A selection of different types of operational energy rating systems used for energy labeling and certificates were reviewed and compared against relative progress in South Africa (Table 4). Environmental labels (e.g. BREEAM (BRE, 2011), LEED (USGBC, 2011), NABERS (Aus DECCW, 2010)) were not included in the comparison as they generally either use similar methods to those being used for national energy certificates to calculate energy credits, or they allocate credits based on the percentage improvement of the building under review beyond the appropriate national benchmark.

The comparison of energy rating systems and energy labels for buildings showed that they were far from consistent between different schemes (Perez-Lombard, *et al.,* 2008; 276). Even in Europe where energy labeling of buildings has been mandatory since 2006, there is no standard for energy labeling, on the contrary, the 2002 Energy Performance of Buildings Directive (EPBD) encouraged countries to apply their own methodologies to meet the requirements for mandatory energy labeling (EPBD, 2008; 3). This was to allow countries the flexibility to integrate energy labeling into existing national policy and energy efficiency schemes. Although energy ratings allow objective comparisons to be made against national benchmarks, the variety in energy rating systems and labeling scales between schemes results in it being difficult to compare buildings that have been reviewed using different schemes.

Table 4: Comparison of some well documented operational commercial building energy certificates from other countries with progress in South Africa

	UK	USA	Australia	South Africa	
Certificate name	Display Energy Certificate (DEC)	EnergyStar®	Building Energy Efficiency Certificate (BEEC)	Energy Barometer	ENERKEY
Mandatory or voluntary?	Mandatory for all public buildings	Voluntary	Mandatory for government occupied buildings, large offices from November 2011	Voluntary	Voluntary
Commercial building activities covered	All	All	Offices, hotels, retail	Corporate head offices, shopping centres, general office buildings, hotels, hospitals	Entertainment & public assembly, theatrical & indoor sport, places of instruction, places of worship, large shops, offices, hotels
Energy rating system	Operational Rating (OR) calculator and other software approved by Secretary of State	EnergyStar®	NABERS Energy	Energy Barometer	ENERKEY
National sample used by rating system	TM46 - compiled from various surveys undertaken in 1990’s	CBECS – updated every 4 years	An unpublished dataset contained within NABERS developed in 1989 from the Australian Building Greenhouse gas Rating (ABGR)	Compared against benchmark developed from buildings entered into labelling system in the previous year	Compared against SANS design target calculated by simulation
Normalising process	Reference values approach	Regression analysis	Regression analysis	Unknown	Computer simulation
Rating for typical building stock	100 (D/E)	50	2.5 star	100	SANS design target
Rating scale	A- G	1 -100	1star - 5 star	0 -150	0 > 1000 kWh/ (m^2a)

2.6 Identifying improvements

The final stage of the benchmark process is to identify improvements that can be made to the building based on the results of the comparison analysis. Some energy certificates have attempted to formalise this process by regulating mandatory reports that have to be supplied with the certificates, which include recommendations for improvements e.g. (UK DCLG, 2008). To simplify the certification process these recommendations are generally fairly generic and can apply to all buildings. It is argued that if the advisory reports are too generic then they could be counterproductive as building owners may select improvements that are not appropriate to their situation (Australian Government, 2010: 29). The UK display energy certificates attempt to avoid this by using approved software to generate advisory reports. This software filters a database of generic recommendations into a shortlist that is applicable to the building in question (UK DCLG, 2008: 38).

A potential lack of trained assessors has been identified, internationally, as a risk to implementing mandatory energy certificates. The production of advisory reports should be carried out by accredited professionals who understand the energy issues in buildings, however training sufficient assessors has been highlighted as an issue in a number of developed countries (UK DCLG, 2007: 16; Australian Government, 2010a: 23). This risk would be exacerbated in South Africa where there already exists a lack of capacity due to the knock-on effect of poor education for large numbers of the population during the apartheid years coupled with the impact of HIV on the working populace.

2.7 Summary

Benchmarks for existing buildings take account of the influence of occupants on energy consumption and are usually generated from empirical data rather than computer simulations. The common metric increasingly used for an energy benchmark in commercial buildings is kilowatt hours per unit of (gross or net) floor area (kWh/m^2). The benchmarks are usually developed from a statistically representative sample of the building stock under review using a survey approach. This research identified the USA CBECS method of data-collection by survey, as a particularly rigorous approach. However critics have highlighted that this approach can be time consuming and hence costly and relies heavily on the cooperation of survey participants.

Benchmarks are usually generated by calculating the median energy intensity of a sample and adjusted to account for variations in certain uncontrollable characteristics, such as variations between the mean annual hours of occupancy of the sample and the building under review.

A rating system can be developed to compare the building under review against the adjusted benchmark. This can be in the form of a software algorithm or a simple percentage improvement over the benchmark. Labels and certificates provide a visual form of representing these ratings.

The data analysis and normalisation methodology used by the EnergyStar rating tool in the USA was identified as a particularly rigorous approach to generating robust benchmarks. The UK energy rating approach provided a useful alternative to the EnergyStar approach, and was more appropriate when data from the original sample was limited.

3 Data Availability

This chapter considers the availability of data required to generate energy benchmarks for commercial buildings. It briefly summarises the availability of data internationally and then focuses on South Africa and specifically commercial buildings in Cape Town.

3.1 Global overview

Collecting data for the initial database is considered a major barrier in the benchmark process. This is due to a range of reasons including complexity and cost (Perez-Lombard *et al.* 2008: 274), data confidentiality concerns (DME, 2003: 36; Moffatt, 2004: 16) and format of data in existing databases (SEA, 2003a: 1-5; Moffatt, 2004: 16). Overall few countries have collected data on national building stock.

Although building data is often collected for a variety of reasons, there is a general lack of coordinated national building stock data in most countries worldwide (Moffatt, 2004: 16). A possible exception is a project in the UK, where a building energy database for commercial buildings has been developed, which coordinates floor area data from the Inland Revenue department, with energy data from sample energy surveys in a selection of cities (Bruhns, Steadman, & Herring, 2000). Extrapolations were made from these small detailed surveys to the stock as a whole and the data entered into a Geographic Information System (GIS). GIS is a way of presenting and analysing data that has a geographical element. This example demonstrates that it is possible to use existing data to create national building stock databases of energy intensity.

3.2 South Africa

The South African Department of Energy highlight the challenges of collecting energy data in South Africa in its national energy digest (South Africa Department of Energy (DoE), 2009: iii). Specifically the lack of accurate, timely and reliable provision of data from their various sources. The initiatives that the Government has undertaken to address these challenges include active participation in the development of the international recommendations on energy statistics (IRES) and actively engaging with Statistics South Africa concerning the collection and production of energy statistics (DoE 2009; iii). Once completed (in February 2011; United Nations, 2010) it is anticipated that the IRES will be used as a basis to develop an energy statistics methodology manual for South Africa. In the mean time good quality energy data is generally difficult to obtain in South

Africa.

For robust benchmarks, good quality energy-intensity indicator data is as critical as energy data. The most common energy-intensity indicator used for buildings is floor area (Perez-Lombard, *et al.,* 2008: 277). The estimated gross floor area of the commercial sector in South Africa in 2006 ranged between 93 million (Milford, 2009: 18) and 88.5 million square meters (Energy Research Centre (ERC), 2007: 6). The higher estimate (Lewis, 2010) was based a combination of data, this included data from Statistics South Africa 'buildings completed', SAPOA Office Vacancy Survey and the Shopping Centre Directory (Statistics South Africa (Stats SA), 2010; South Africa Property Owners Association (SAPOA), 2009; South African Council of Shopping Centres (SACSC), 2010). The lower estimate (DeVilliers, 2000) was based on assuming a correlation between floor area growth and national GDP. There are therefore a range of estimates of floor area for the commercial buildings sector in South Africa.

In addition to energy-intensity data, data on the composition of the commercial building stock is invaluable when creating benchmarks; this allows similar building activities to be grouped to allow more specific benchmarks. An estimate of the composition of the commercial building stock in South Africa was undertaken in 1993 (Anderssen *et al.,* 1993), and although the original report is no longer available the figures have been recycled in numerous reports since (PDG, 2007: fig 6.1; ERC, 2002; SEA, 2003a: 5-5; Piani, 1995: 1). A more recent and comprehensive estimate is published in the greenhouse gas mitigation report (DeVilliers, 2000: 18). This estimate divides the commercial sector into eight categories and has been used in developing the future energy models for South Africa (Scenario Building Team, 2007). However there is no clear reference as to how the portion of total floor area assigned to each building activity was calculated. An empirical figure for the current composition of the commercial building stock in South Africa is therefore still lacking.

These national statistics, although useful for policy decisions and to identify overall data availability in South Africa, cannot provide the detailed information required to understand energy use within each economic sector and create benchmarks (Mortimer *et al.,* 1999; 451). A bottom up approach often incorporating a survey technique such as the USA Commercial Buildings Energy Consumption Survey (CBECS) is considered to be a more appropriate approach (Mortimer *et al.,* 1999; 451; Perez-Lombard *et al.,* 2008; 274). A bottom-up approach to collecting energy consumption data in buildings refers to the practice of analysing individual buildings and then applying this to a larger stock of buildings. In South Africa, national data on energy consumption and floor area is currently more readily available than detailed bottom up data on individual buildings or specific groups of buildings.

3.3 The City of Cape Town

A recent study undertaken by PJ Carew Consulting and the Cape Town Partnership in 2008 (DeVilliers-Leach, 2008: 63, 64), used the survey approach on a small scale to generate benchmarks from a sample of 20 commercial buildings in the City of Cape Town, the survey used net floor area as the energy-intensity indicator. The results were published in the form of the median, upper quartile and lower quartile benchmarks. However, the sample is a relatively small and not statistically representative of the commercial stock in Cape Town, although it is considered to be representative of 'larger' (>5000 m^2) central business district type buildings in Cape Town, of which there is an estimated 100 buildings in the central City (DeVilliers-Leach, 2008: 64). A number of other energy consumption studies undertaken on single-buildings in Cape Town (Devenish, 2010; SEA, 2005) are not generally appropriate for generating benchmarks due to a variety of reasons depending on the study, including incorrect metrics and biased samples being un-representative of the commercial building stock in Cape Town.

Historically, detailed energy data for the City of Cape Town has been obtained using a top down approach based on total fuel sales data for the region (Sustainable Energy Africa (SEA) 2003a; Winkler *et al.,* 2005; SEA 2006; PDG, 2007). The top-down approach refers to the practice of collecting total energy-consumption data for a large number of buildings and dividing these data amongst individual buildings or end uses by applying a standard consumption factor to each building or end use. Notably, all of the reports that publish energy data on the City of Cape Town include absolute energy consumption figures rather than energy intensities and detailed data on the composition of the sectors is lacking. The composition of the commercial building stock in the City of Cape Town has not been studied. Where composition is referred to in previous reports on energy in Cape Town, national figures calculated in 1993 have been recycled (ERC, 2002; SEA, 2003a: 5-5; PDG, 2007: fig 6.1). Detailed data for the City of Cape Town has historically been obtained using a top down approach that provides insufficient data for energy benchmarking.

Detailed data on individual buildings is collected by a number of departments in the City of Cape

Town municipality. Currently there are six different business units in the municipality that collect building related data and they all use different systems. Three of these business units collect data that could be used for developing energy benchmarks; the revenue department, air quality department and valuation department. However, the existing collection of building related data by the City of Cape Town municipality is not integrated.

The revenue department collects monthly electricity billing data for all municipality customers (CCT, 2007a). The municipality electricity billing database has the potential to be able to provide monthly electricity data for all consumers supplied by the municipality in the City of Cape Town. Energy data for the City of Cape Town from 2007/2008 confirmed that the majority of the fuel consumed in the City was electricity, and 83% of the City of Cape Towns electricity demand was supplied by the municipality (see Error: Reference source not foundError: Reference source not found). The municipality electricity database could therefore provide an invaluable data resource if it could be exploited fully. Detailed billing data is theoretically available for all electricity consumers supplied by the municipality but data is extracted on a building by building basis and hence data on large numbers of buildings is very time consuming to extract.

The air quality department estimates consumption data for other fuels in the annual survey of registered industrial and commercial fuel burning appliances (CCT, 2007b). This database provides an average consumption for one month for each fuel for all customers in Cape Town with registered appliances.

The valuation department collects building data on all commercial, residential, agricultural and sectional properties (CCT, 2009c) for calculating rates (taxes). The valuation database includes information on gross floor area, construction type and age of buildings. Data is extracted from the valuation database on a building by building basis and hence data on large numbers of buildings is very time consuming to extract.

The different systems used to collect the building related data, use a combination of automatic interfaces, manual interfaces and external interfaces which are not integrated and often results in missing data and inaccurate information. However, the municipality are in the process of streamlining and updating their property database systems using a state of the art integrated spatial information system (ISIS) (Stelling & Mastoroudes, 2010). This streamlining process has the potential to have a large positive impact on access to data from the municipality.

The streamlining process is based around the concept that all of the databases will be linked by a common thread - the LIS-KEY. The LIS-KEY is a number generated by the City of Cape Town's Land Information System to uniquely identify a property. This number will be seen as the most important identifier of a property and will supersede the existing ERF number (CCT, 2006: 6) (the ERF number is the existing national system intended to be a unique identifier for each building plot, however the system has become confused over the years as plots have been subdivided and municipality boundaries changed). It is envisaged that the existing data will be cleaned up and entered into a new system that links SAP (currently used to collect billing data) and GIS software. Most municipalities in South Africa already use GIS to some extent (Das, 2009). Each building on the GIS drawing will be linked with the SAP database providing related property information. The expertise to operate such a system currently resides in Germany and it was highlighted that extensive training would be required to realise this vision (Stelling & Mastoroudes, 2010). This system if successfully implemented would be the first of its kind.

3.4 Data gaps

Data on energy consumption by end use is in short supply globally and South Africa is no exception to this. In the USA the EIA overcame the lack of empirical data by estimating the portion of energy consumed by a number of end uses using computer simulation and reconciling this with the measured energy consumption (USA EIA, 2009a).

In South Africa a top down approach has been used to estimate energy consumption by end use for national commercial stock (DeVilliers, 2000: 18). The annual energy intensity is estimated for a number of building activities and standard consumption factors applied to each building activity for six end uses. However, although the approach is clear, the origin of the standard consumption factors is poorly described rendering these estimates meaningless for future studies.

In the City of Cape Town, end use energy data is estimated for the commercial sector in only one of the four reports published on energy consumption in the City in the last ten years (Winkler *et al.*, 2005). The lack of measured data is overcome by estimating typical energy consumption using a number of assumptions relating to hours of use and average energy characteristics of individual energy-consuming appliances (Winkler *et al.*, 2005: 13 -14).

3.5 Summary

In summary, data availability in South Africa is comparable with other countries worldwide. In common with other countries, uncoordinated data collection from different stakeholders, means that top down energy-performance data is more readily available than data for individual buildings.

This is a problem because the recognised approach to generating national benchmarks is by using a bottom up approach to data collection, such as a survey of a statistically representative sample of national buildings.

The South African municipalities have the opportunity to 'leap-frog' other countries with regard to collecting bottom up data. By introducing coordinated data collection processes that link building data with electricity billing data the municipalities have the opportunity to develop comprehensive databases containing energy related building characteristics for the commercial sector. The City of Cape Town is addressing this with the introduction of the state of the art data-collection system ISIS.

This study investigates the potential of this new streamlined data-collection system by linking data for a sample of buildings taken from the current municipality databases and generating benchmarks from this sample.

As data for the whole building is more readily available for individual buildings in the City of Cape Town than energy consumption by end use, two types of benchmark were generated using different approaches;

1. A **whole building benchmark** that used bottom up approach of collecting building data for a sample of individual buildings to generate a typical (median) energy intensity for the whole building.

2. An **end use benchmark** that used the top down approach of calculating the total energy-intensity data for the commercial sector in Cape Town and dividing these data amongst six individual end uses (lighting, water heating, space heating, ventilation & cooling, refrigeration and other) by applying a standard consumption factor to each end use.

The process of developing benchmarks for Cape Town using these two approaches identified specific data gaps to be filled during the data streamlining process being undertaken by the City of Cape Town. By filling these data gaps the new database will provide access to energy-performance data for all commercial buildings in Cape Town from which robust benchmarks can be established.

4 Whole building benchmarks for Cape Town

This chapter presents the analysis process and results for generating whole building energy benchmarks for commercial buildings in Cape Town.

4.1 Methodology

Whole building data was acquired from the City of Cape Town municipality databases and analysed using methods based on well established international examples (Field, 2008; USA EPA, 2010). The procedure used to generate the benchmarks was as follows:

- A **dataset** was developed containing details on actual energy consumption and operational characteristics of a sample of buildings.
- **Filters** were applied to the sample dataset to ensure the dataset was relevant to the commercial building sector, to divide the data into sub-sectors based on building activity and to ensure that each building had the appropriate energy-indicator data.
- **Whole building benchmarks** were generated by calculating the median energy intensity for the population in each building activity category within the sample.
- Methodologies and equations were developed to **normalise** the benchmarks and the building under review.

The following sections explore in detail each of the above stages.

4.1.1 Dataset

The dataset for electricity consumption was developed from a sample of sales data obtained from the City of Cape Town SAP ERP database (CCT, 2007a). Monthly billing data was provided for a sample of electricity consumers on the municipality large power user (LPU) tariff for a twelve month period from October 2006 to September 2007. The sample contained electricity-consumption data for 1200 customers in the City of Cape Town. The data contained the top 75% electricity consumers on the municipality LPU tariffs (see Appendix 1: Electricity consumption (SAP sample)).

For levels of consumption of other fuels (coal, wood, LPG, HFO, diesel and paraffin) the dataset was developed from the average monthly sales data from the municipality air quality department's 'annual survey of registered industrial and commercial fuel burning appliances' (CCT, 2007b). The survey provided an average consumption for one month for each fuel which was multiplied by 12 to provide an estimate for the year. The air quality database contained consumption data for six different fuel types for 206 commercial customers in the City of Cape Town (see Appendix 2: Other fuels consumption).

4.1.2 Filters

Data filters were applied to the samples in order to define the benchmarks specific to particular building activities, and overcome any technical limitations in the data.

The following four filters were applied to the dataset:

1. Building sector

The building sectors represented in the sample were agricultural, residential, public sector, industrial, unknown and commercial. All buildings not in the commercial sector were excluded from the sample. The commercial sector was defined as all non-residential buildings except public-sector buildings, industrial, agricultural, and unidentified buildings. The commercial sector included mixed use buildings as recommended by UNEP (see UNEP SBCI, 2009b). Mixed use was defined as buildings in which the gross floor area used for commercial purposes was equal to or greater than 50% of the total gross floor area of the whole building (USA EIA, 2009d). Although similar, the term 'commercial sector' is usually used in a different context to the term 'services sector', which generally refers to an economic sector rather than activities specifically undertaken within buildings (US Census Bureau, 1997).

In the electricity sample two methods were used to deduce the sector associated with each customer. The first method identified the existing use of the building from the municipality on-line valuation database (CCT, 2009c). If the building could not be found in this database then the customer's electricity billing name was used to deduce the building activity. For buildings using other fuels, the sector was identified from the 'nature of business' code assigned to each registered building.

From the electricity sample, the sector could be identified for 78.8% of the customers. Of all the customers in the sample 35.2% were identified as being commercial; 29.2% as industrial; 12.4% as public sector; 1.8% residential, 0.3% agricultural and 21.3% unknown (Figure 1). After the sector filter had been applied there were 422 commercial electricity customers remaining.

The commercial electricity customers in this sample were responsible for approximately one third of the total annual electricity consumption in the commercial sector in the City of Cape Town but only constituted just over one percent of the commercial customers (see Error: Reference source not found).

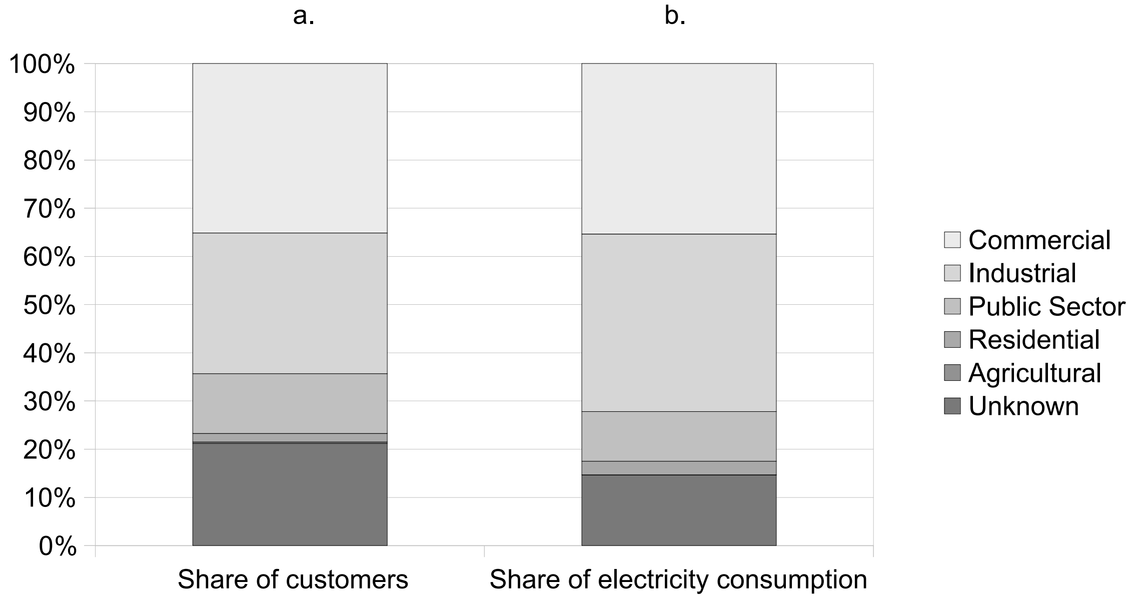

Figure 1: Share of customers 'a' and energy consumption from electricity 'b' by building sector in the City of Cape Town, Oct 2006 to Sept 2007.

From the other fuels sample, the sector could be identified for 98.9% of the customers (see Appendix 2: Other fuels consumption). Of all the customers in the sample 43.2% were identified as being commercial; 53.31% as industrial; 1.84% as public sector, 0.55% as power generation and 1.1% unknown (Figure 2). After the sector filter had been applied there were 235 commercial 'other fuels' customers remaining.

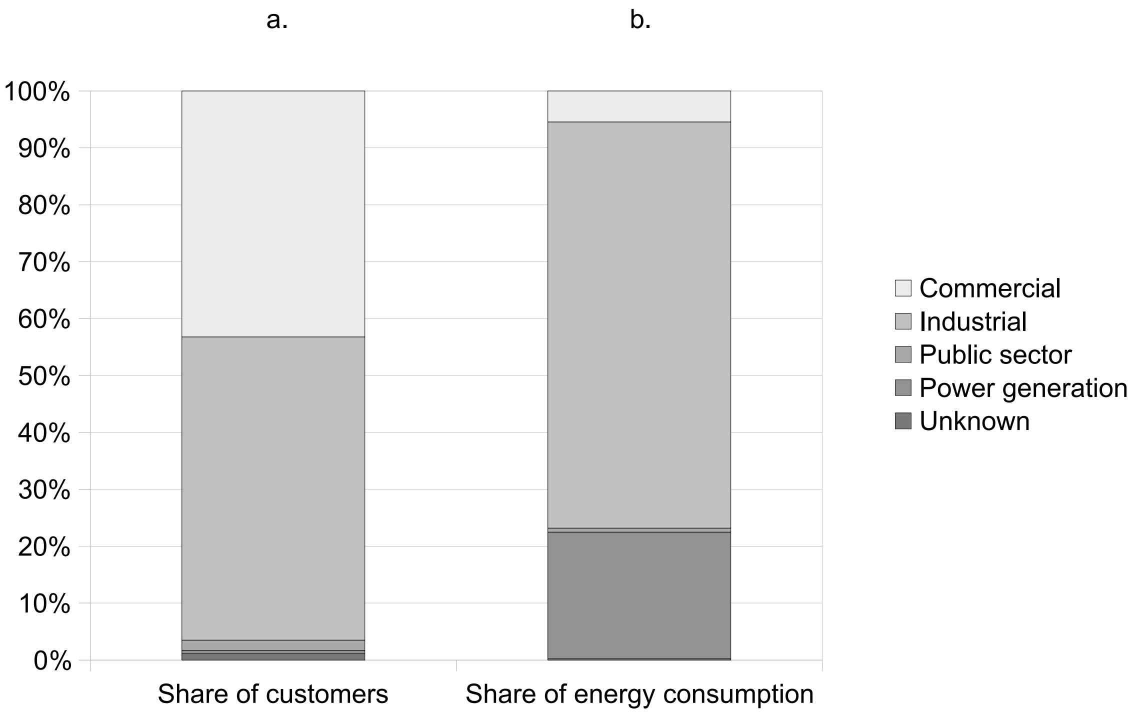

Figure 2: Share of customers 'a' and energy consumption from other fuels 'b' by building sector in the City of Cape Town, Oct 2006 to Sept 2007.

2. Building activity

The remaining customers were further divided into nine building activity categories (Table 4). Any buildings that could not be classified into these categories were discounted. These categories were developed from reviewing existing building performance databases (USA EIA, 2003; Jones, 2004: 20.1- 20.14; Field, 2008: 4-5) and reviewing standard classification systems used internationally that define economic activity (US Census Bureau, 1997). The final selection of building activities (Table 5) followed those used in the greenhouse gas inventory for South Africa (DeVilliers, 2000: 18), with the addition of mixed use buildings as recommended in the CCM (UNEP SBCI, 2009b: 8).

The same methods that were used to identify the building sector were used to deduce the predominant activity being undertaken in the building.

Table 5: Building activity groupings for the commercial sector used in this study.

Building activity group	**Building activities included in this group**
Retail	Shopping malls, supermarkets, food shops, trade retail premises
Catering	Restaurants, fish shops
Accommodation	Hotels, hostels, retirement homes, caravan parks In the Cape Town electricity sample all the hotels included in the final dataset were identified as large business hotels.
Office	Banks, offices
Warehouse	Warehouses, cold storage, shipping container storage, catalogue shops, transport related buildings
Education facilities	Universities, technical universities, private colleges, high schools, primary schools, training centres. Government schools are not included
Healthcare facilities	Private hospitals and clinics including private GP services
Mixed use	Buildings that contain activities classified in more than one sector and in which the gross floor area used for commercial purposes is equal to or greater than 50% of the total gross floor area of the whole building.
Other	Place of entertainment (theatres, cinema, stadium, exhibition) clubs, telecommunications, fitness centres, golf clubs, service stations, post offices, publishing houses, places of religious worship. Note: large laundry/dry cleaners were included in industrial

The customers using electricity were filtered into the nine building activity categories (Figure 3). In this sample, the retail sector consumed the largest portion of electricity and also constituted the largest number of customers. Offices were the next largest electricity consumer. The other sectors were substantially smaller in terms of both electricity consumption and the number of customers.

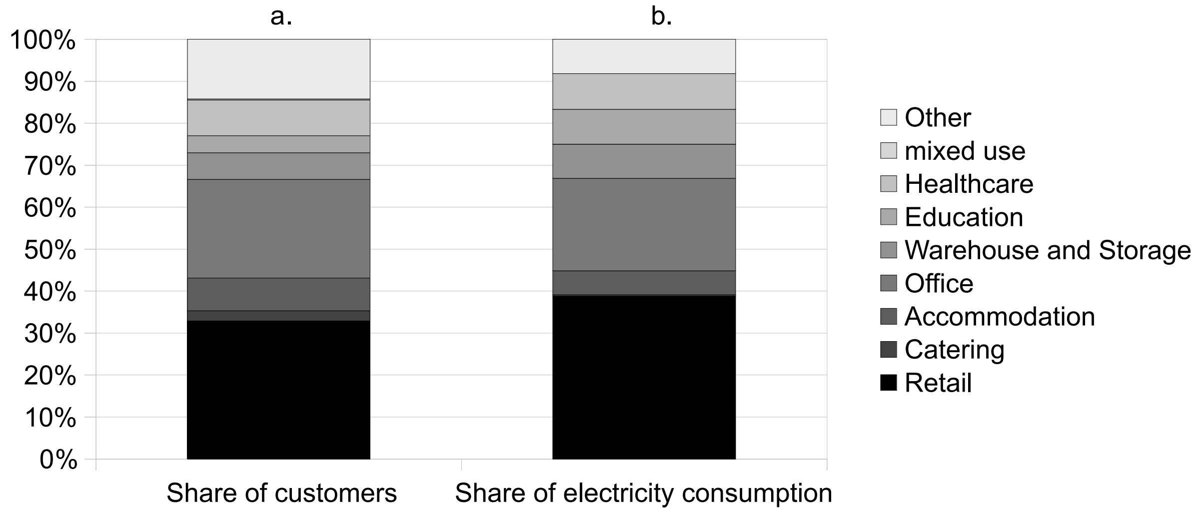

Figure 3: Share of customers 'a' and energy consumption from electricity 'b' by building activity in the City of Cape Town, Oct 2006 to Sept 2007.

The customers using 'other fuels' were also filtered into the nine building activity categories (Figure 4). In this sample, catering accounted for the majority of the customers, these were mostly pizza restaurants that used relatively small quantities of wood to fuel their pizza ovens. Healthcare and education consumed the most non electrical energy, mostly coal and liquefied petroleum gas (LPG) used to fuel boilers.

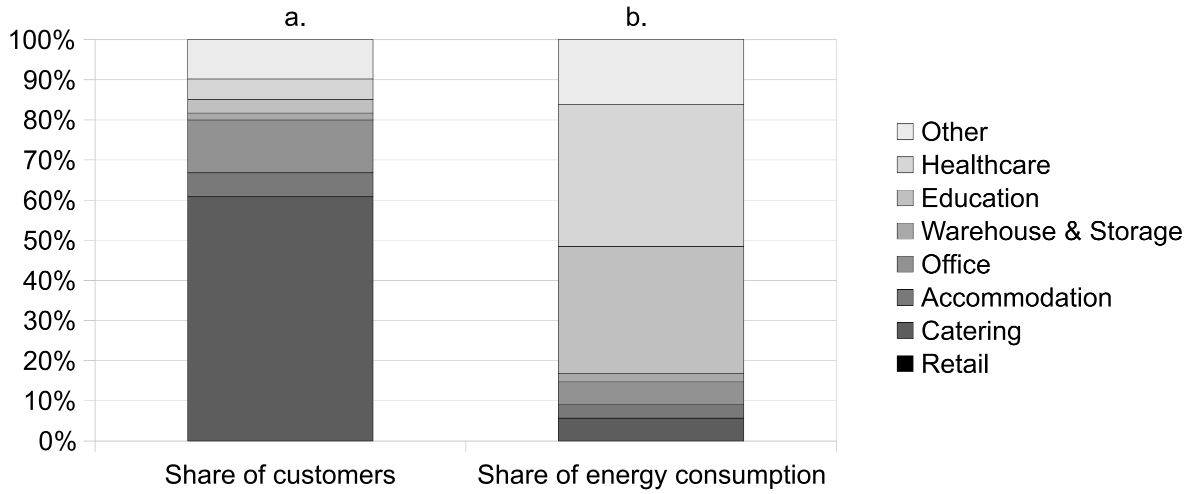

Figure 4: Share of customers 'a' and energy consumption from other fuels 'b' by building activity in the City of Cape Town, Oct 2006 to Sept 2007.

3. Energy-intensity indicator

The energy-intensity indicator selected in this study for all building activities except hotels was floor area. For hotels the energy-intensity indicator was selected as the number of bed rooms. Any building for which an energy-intensity indicator could not be determined was excluded from the sample.

To obtain floor area data for each building in the electricity sample, the ERF number for each building was used to access the relevant information in the on-line valuation database. For 'other fuels' the physical address was used as the ERF number was not provided.

The following assumptions were made regarding the data presented in the valuations on-line database;

- The area provided in the general overview refers to the ERF area, i.e. the area of the plot of land on which the building was located.
- The area provided in the detailed summary refers to the gross area of all floors in the building.

The area in the detailed summary was, in many cases, split into a number of entries. For each entry the base floor, floor number and 'extent' were provided. The following definitions of terms were taken from the non-residential data collection manual developed by the municipality to guide the data collection process (CCT, 2006: 12);

- Base floor – The lowest floor level where the specific group[1] first occurs
- Floor number – The number of floors identical to the base floor that forms the group.
- Extent – base floor area in square meters[2]

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[1] The manual required valuers to identify different sections of the building that had different physical characteristics and then to further identify areas within each section that had different uses and classify each of these areas as a group.

[2] To calculate the total gross floor area, the number of floor levels was multiplied by the extent.

If a building appeared in the valuation database with more than 10 floor area entries (some buildings had 200+) in its detailed breakdown, the area was not calculated and the building was discounted from the data set. These data were extremely time-consuming to collate and often appeared unreliable. This occurred in 44 cases; at least 6 of these had over 200 separate floor area entries.

Floor area data was not available from the valuations database for any of the buildings in the 'other fuels' sample. This meant that energy benchmarks could not be developed any further for fuels other than electricity. As electricity dominates energy consumption in commercial buildings in Cape Town (see Appendix 5: Energy consumption by end use), it was considered that electricity benchmarks would provide a useful indicator of energy performance for the Cape Town commercial sector. However, when comparing these benchmarks against other comparable building stock, it was necessary to include an assumption for other fuels. For these comparisons the energy-intensity was adjusted based on the proportion of other fuels (4.3%) to electricity (95.7%) consumption in the commercial sector in Cape Town in 2007 (see Appendix 5: Energy consumption by end use).

Hotel room data was obtained by identifying the hotels by their billing name or ERF number and extracting the data from the hotel websites.

For some building activities, energy-indicator data was only available for a small number of buildings (<10) (Figure 6). In these instances the buildings were added to the 'other' category to provide a larger sample size.

There was no known systematic bias in the electricity sample relating to the availability of energy-indicator data. As such, applying the energy-indicator filter produced a randomised sub-sample of the original sample. After the energy-intensity filter had been applied to the sample there were 158 commercial electricity customers remaining (Figure 6).

Table 6: Electricity sample sizes after all the buildings in the commercial sector had been divided by building activity n(1), and showing the sample size for each building activity after all the buildings where the energy-intensity indicator could not be determined had been excluded n(2).

Building activity	**n (1)**	**Energy-intensity indicator**	**n (2)**
1. Retail	139	Floor area	50
2. Catering	10	Floor area	2
3a. Accommodation – large business hotel	20	Number of bedrooms	12
3b. Accommodation – other than hotel	13	Floor area	3
4. Office	99	Floor area	60
5. Warehouse & Storage	27	Floor area	5
6. Education	17	Floor area	3
7. Healthcare	36	Floor area	9
8. Mixed use	1	Floor area	0
8. Other	60	Floor area	13
New 'Other' (sum of 2, 3b, 5, 6, 7 & 8)	-	Floor area	35
TOTAL	422		158

4. Analytical

To test whether the selected energy-intensity indicators were legitimate for the Cape Town sample, a statistical linear regression analysis was undertaken on each building group activity (where sample sizes were sufficient). The analysis was undertaken to determine the relationship between electricity consumption and the selected energy-intensity indicator. During this process an analytical filter was applied to eliminate outlier data points that showed different behaviour to the rest of the data.

The analysis indicated that prior to the analytical filter being applied there was a moderately strong positive correlation between electricity consumption and floor area for the offices sample but for retail and the newly created 'other' category the correlation between floor area and energy consumption was weak (Table 7).

Examination of the residuals revealed that buildings with very low (less than 100kWh/m^2.annum) and very high (greater than 500 kWh/m^2.annum) energy intensities invalidated the assumptions of a linear model. Floor area was therefore considered only to be a suitable energy-intensity indicator for buildings with energy intensities greater than 100kWh/m^2 and less than 500kWh/m^2 (Table 8).

In the case of retail the low energy intensities were generally associated with warehouse style retail premises, this was deduced from the customer billing names. The high energy intensities, were associated with large retail businesses that encompassed many retail outlets. It was unclear from the billing data, in these instances, whether the billing address related to the head office or to the premises that were being billed. Hence there existed a potential that the floor area only related to the head office when it should have included a number of retail outlets, thus resulting in high energy intensities.

For the office sample the reason for the very high and very low energy intensities was less clear from the billing names. Possible reasons for these outliers are that there were anomalies between the buildings that were registered in the billing data and those registered in the valuations database, or that some offices had very low occupancies or were unoccupied resulting in uncharacteristically low energy intensities.

Based on the linear relationship indicated by the statistical analysis, the floor area was considered to be a suitable energy-intensity indicator only for buildings with energy intensities greater than 100kWh/m^2 and less than 500 kWh/m^2 and any buildings falling outside this range were excluded from the sample. After this analytical filter had been applied there remained 101 commercial electricity customers with floor area as the energy indicator.

Table 7: Linear regression on influence of floor area on energy consumption in retail, office and other commercial buildings including all buildings in the samples.

Building activity	**n**	**r^2**	**r**	**P**
Retail	52	0.15	0.39	0.004
Office	60	0.58	0.762	0.000
Other	35	0.055	0.235	0.181

Table 8: Linear regression on influence of floor area on energy consumption in retail, office and other commercial buildings with the analytical filter applied.

Building activity	**n**	**r^2**	**r**	**P**
Retail	40	0.872	0.934	0.000
Office	41	0.838	0.916	0.000
Other	20	0.836	0.914	0.000

For business hotels there was a strong correlation between number of bed rooms and energy consumption (Table 9) and no obvious outliers were identified. However, the sample was relatively small and so it was necessary to treat the results with caution.

Table 9: Linear regression on influence of number of bedrooms on energy consumption in a sample of large business hotels in the City of Cape Town.

Building activity	**n**	**r^2**	**r**	**P**
Hotel	12	0.607	0.799	0.003

4.1.3 Sample characteristics

The sample was derived on the basis of available data and was not a representative sample of the commercial building population in the City of Cape Town. This resulted in the sample being systematically biased towards large electricity consumers as it only contained consumers on the large power use tariffs and the sample included the top 1200 consumers on these tariffs. For the same reasons the hotel sample was bias towards larger hotels (11 of the 12 hotels had more than 100 rooms).

The majority of the buildings in the samples were built within the last 50 years. A quarter of the retail buildings were built in the last decade indicating that the retail sample, in particular, represents a fairly new building stock. This reflects the economic situation in Western Cape; demonstrating continued growth in the services sector, since the fall of Apartheid in the mid 1990's (Smith, 2005: 19).

The distribution of the retail building sample in Cape Town by a) annual energy intensity, b) building age and c) floor area, is shown in Figure 5.

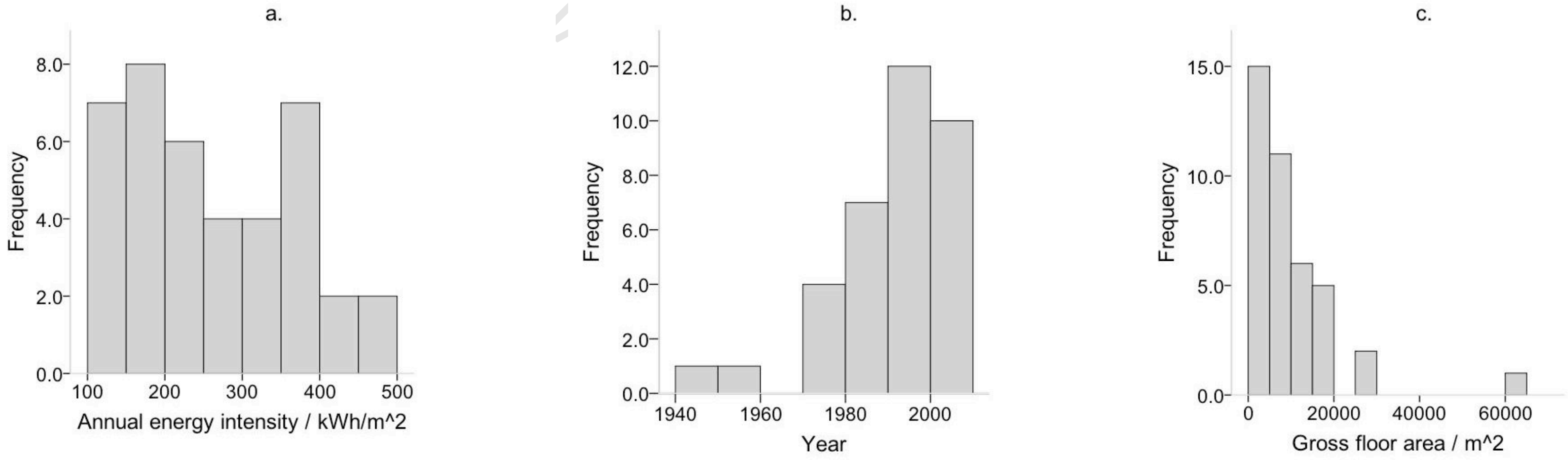

Figure 5: Distribution of the retail building sample in Cape Town by

a. annual energy intensity (median =241.76 kWh/m^2, mean = 259.29 kWh/m^2, Std. Dev = 111.6, n = 40).

b. year of construction (median=1990, mean = 1989, n = 35).

c. gross floor area (median=6566.5m^2, mean 9472.6m^2, n = 40)

The distribution of the office building sample in Cape Town by a) annual energy intensity, b) building age and c) floor area, is shown in Figure 6.

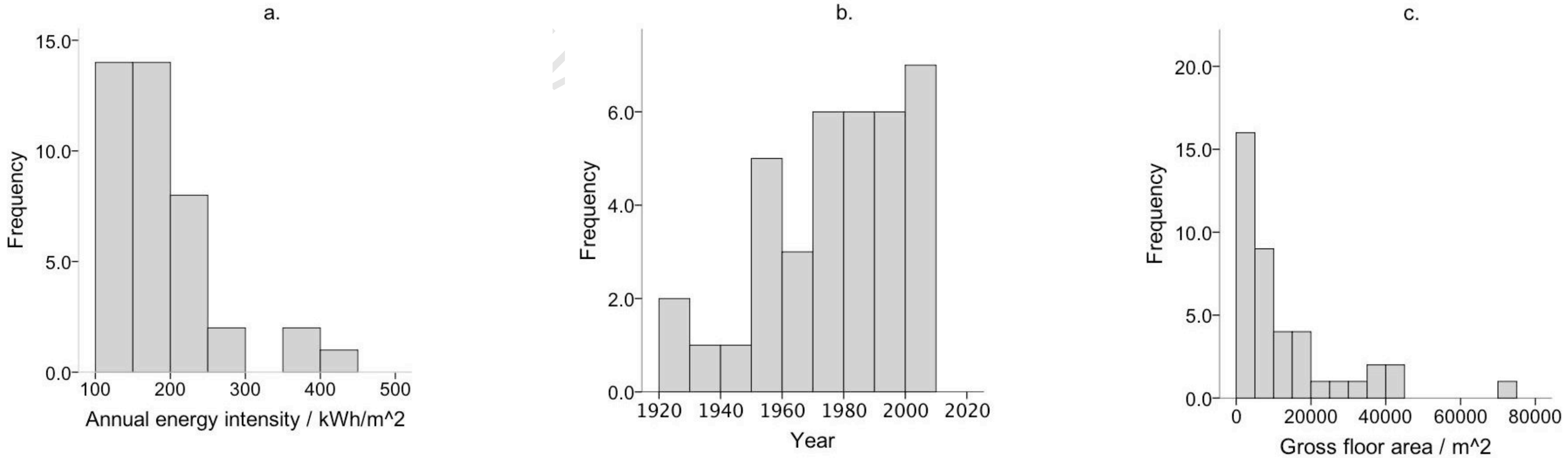

Figure 6: Distribution of the office building sample in Cape Town by

a. annual energy intensity (median =176.14 kWh/m^2, mean = 188.38 kWh/m^2, Std. Dev = 69.71, n = 41).

b. year of construction (median= 1980, mean 1976, n = 37).

c. gross floor area (median= 6198.00m^2, mean = 12641.85m^2, n = 41).

The distribution of the hotel sample in Cape Town by a) annual energy intensity, b) number of bedrooms Figure 7.

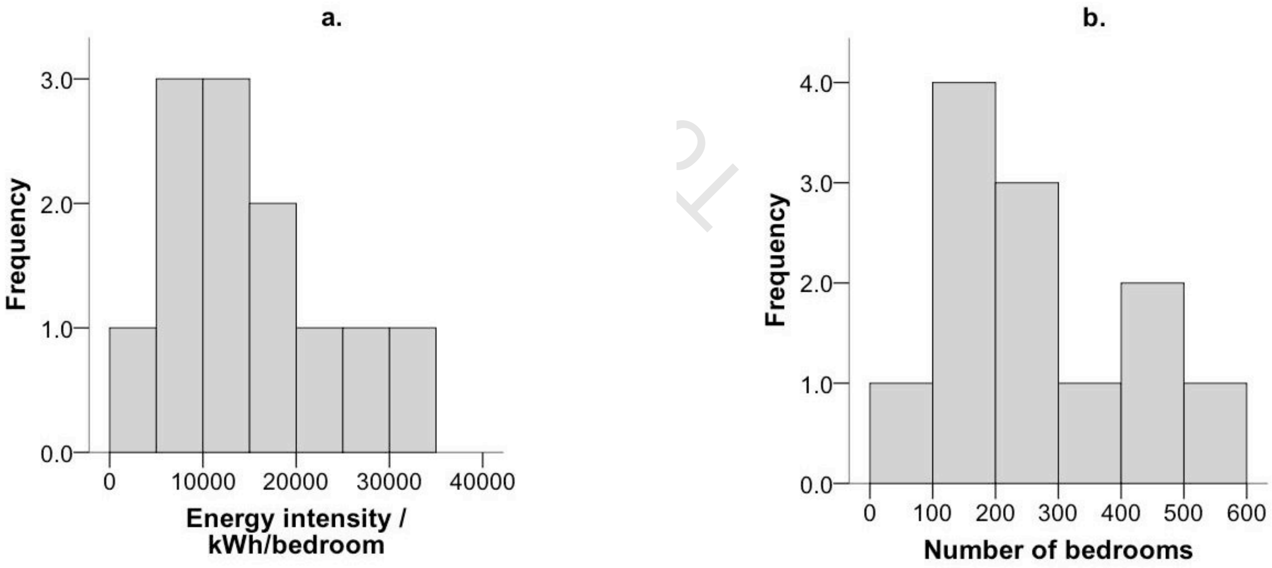

Figure 7: Distribution of the hotel building sample in Cape Town by

a. annual energy intensity (median =13,473.9 kWh/room, mean = 15,069.22 kWh/room, n =12).

b. number of bedrooms in the business hotel sample (median 201.5, mean = 259, n =12).

The distribution of the remaining commercial buildings in the sample in Cape Town by a) annual energy intensity, b) building age and c) floor area, is shown in Figure 8.

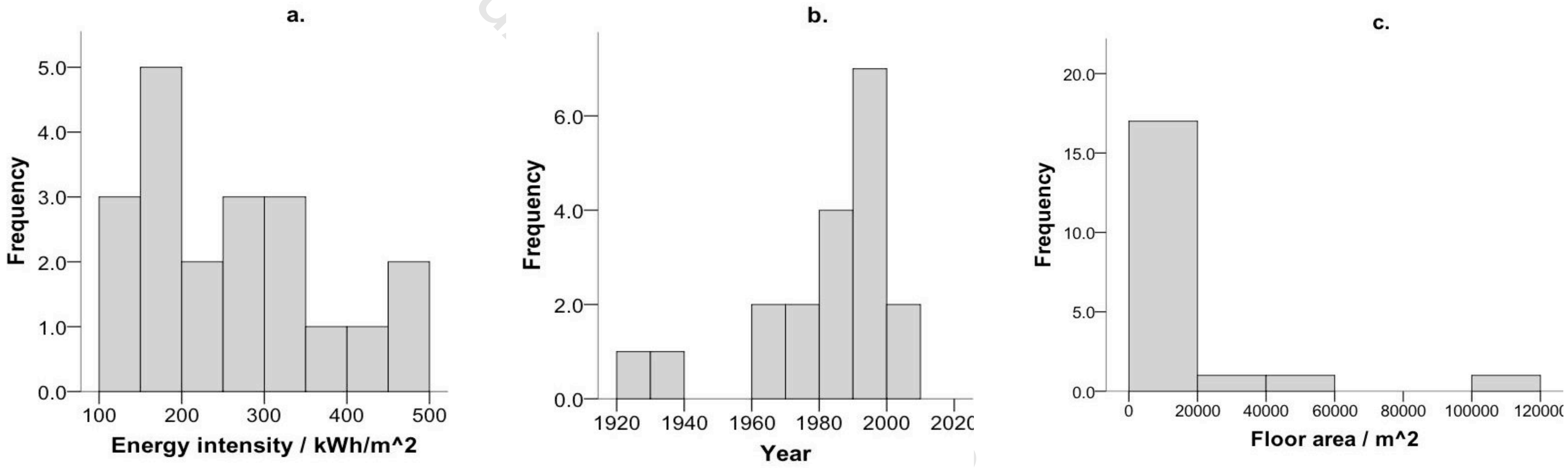

Figure 8: Distribution of the other building sample in Cape Town by
a. annual energy intensity (median =250 kWh/m^2, mean = 261.12 kWh/m^2, Std. Dev = 106.2, n = 20).
b. year of construction (median=1985, mean = 1980, n = 19).
c. gross floor area (median= 4184m^2, mean = 11944.45m^2, n = 20).

4.2 Results

For each building activity benchmarks were calculated that represented typical, good and poor practice for electricity consumption (Table 10) and all fuels (Table 11).

Table 10: Electricity benchmarks for Retail, Office, Other and hotels in the City of Cape Town.

Building activity	n	Metric	median (typical)	mean	Upper quartile (good)	Lower quartile (poor)
Retail	40	kWh/m^2 (gross floor area)	241.8	259.3	162.8	357.9
Office	41	kWh/m^2 (gross floor area)	176.1	188.4	140.2	212.9
Other	20	kWh/m^2 (gross floor area)	250.0	261.1	163.9	335.9
Hotels	12	MWh/bedroom	134.7	150.7	93.1	219.5

Table 11: All fuels benchmarks for a selection of commercial building activities in the City of Cape Town.

Building activity	n	Metric	median (typical)	mean	Upper quartile (best practice)	Lower quartile (poor)
Retail	40	kWh/m^2	252.7	271.0	170.1	374.0
Office	41	kWh/m^2	184.0	196.9	146.5	222.5
Other	20	kWh/m^2	261.2	272.8	171.3	351.0
Hotels	12	MWh/bedroom.annum	140.8	157.5	97.3	229.4

5 End use benchmarks

This chapter presents the analysis process and results for generating energy benchmarks by end use for commercial buildings in Cape Town.

5.1 Methodology

A top down approach was used to estimate energy consumption by end use, because empirical data was not available. This approach involved calculating the total energy intensity for the commercial sector in Cape Town and dividing these data amongst individual end uses by applying a standard consumption factor to the data for each end use.

The procedure used to generate the benchmarks was as follows:

- Total **energy consumption by fuel** was estimated for the Commercial sector in the City of Cape Town
- Total **floor area** was estimated for commercial buildings in the City of Cape Town
- **Building activities** were identified which had corresponding floor area data
- For each building activity group **standard consumption factors** were identified for each end use and each fuel
- Standard consumption factors were applied to the total energy consumption for each building activity group and from this **end use benchmarks** generated.

The following sections address each of the above points in turn.

5.1.1 *Energy consumption by fuel*

Electricity sales data was obtained from the City of cape Town and Eskom for all buildings in the City of Cape Town. This data was available for a different time period than the smaller sample used to develop whole building benchmarks, it spanned a 12 month period from April 2007 to March 2008 (see Appendix 3: Electricity consumption (City of Cape Town)).

The Eskom data was available by sector, whereas the municipality data was available by tariff. As the municipality tariffs were not always sector specific, these data required a number of assumptions to identify the share of electricity consumed by the commercial sector;

- It was assumed that all customers on the municipality small power user (SPU) tariffs were commercial customers, although it should be acknowledged that there were potentially a few exceptions to this rule.
- For municipality customers on the large power user tariffs (LPUs), public sector consumers were identified by the tariff name. The remaining LPUs were divided between commercial, industrial, residential, agricultural and unknown using the proportions calculated from the detailed LPU sample used to develop the whole building benchmarks.
- Warehouses were included in the industry sector for this analysis so that the definition of commercial sector corresponded (as far as possible) with that used in estimating the floor area of commercial buildings in Cape Town. A list of building activities incorporated in the commercial sector was not available for Eskom's billing data or for the municipality small power tariffs.

For energy consumption from all other fuels (wood, coal, LPG, HFO, paraffin & diesel) the same sample was used as for developing whole building benchmarks. It was assumed that this sample included all significant fuel users in the City of Cape Town. The estimate of total energy consumption by each fuel indicated that electricity consumption dominates in the commercial sector in Cape Town (Figure 9).

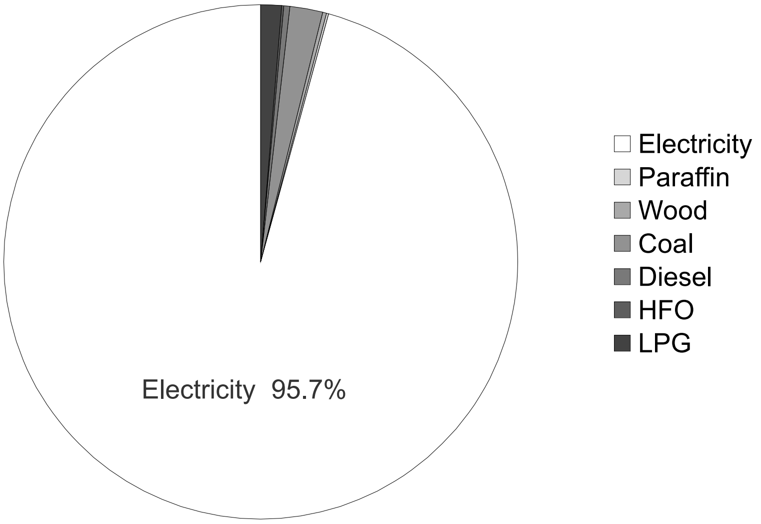

Figure 9: Energy consumption by fuel for the commercial sector in the City of Cape Town 2007/2008 (for full calculations see Appendix 5: Energy consumption by end use).

5.1.2 Floor area

To establish an energy-intensity indicator for the entire commercial sector in Cape Town, it was necessary to obtain a value for the gross floor area of all commercial buildings in Cape Town in 2007. Empirical data on floor area in this year was unavailable and so an estimation was made based on a combination of a published floor area estimate for the commercial sector in South Africa in 1994 and on empirical data on the floor area of commercial buildings constructed in South Africa and the Western Cape in the period from 1995 to 2007.

A report by De Villiers (2000:18) estimated the floor area for the commercial sector in South Africa for 1990 as 65 million square meters. DeVilliers also predicted the floor area for a selection of subsequent years based on the assumption that floor area grew at 70% of commercial GDP (2000: 18). From 1993 to 2007, annual data on the floor area of newly constructed buildings in South Africa was available for the three building activity groups of 'office and banking', 'shopping space' and 'other non-residential space' (Stats SA, 2010). Data for 'industrial & warehouse' and 'additions and alterations' was also available but these data were excluded as the proportion allocated to the commercial sector could not be distinguished. A baseline floor area prediction for 1992 was not published by DeVilliers, hence the subsequent closest year of 1994 was taken as the baseline.

Adding the floor area of newly constructed buildings to the baseline value available from the DeVilliers predictions gave an estimated floor area for the commercial sector in South Africa for 2007 as 97.85 million square meters (see Appendix 4: Floor area estimate).

To estimate the floor area of commercial buildings in Cape Town from the above data, two key assumptions were made:

1. The ratio of commercial floor area built in the Western Cape to that built in South Africa between 1995 to 2007 (0.132:1) was the same as the ratio of floor area of commercial buildings in the Western Cape to that in South Africa in 1994.

2. Population is directly proportional to commercial floor area. This was based on the assumption that GDP and population are linked and that GDP and floor area growth are linked (DeVilliers, 2000). GDP data could not be used directly as it was not available for the Western Cape and Cape Town.

Using these two assumptions the floor area of commercial buildings in Cape Town was estimated as being 8.24 million square meters in 2007 (for full calculations see Appendix 4: Floor area estimate).

5.1.3 Building activities

The building activity groups used for the end use benchmarks were defined by the availability of floor area data for the Cape Town commercial building population. As described in the previous section, floor area data was based on empirical values for buildings completed in the Western Cape between 1993 and 2007. These data provided a share of floor area for three building activity groups;

- Office and banking (38%)
- Shopping space (28%)
- Other non-residential space (34%)

5.1.4 Standard consumption factors

5.1.4.1 Electricity

Typical electricity energy intensities for six end uses (lighting, space heating, water heating, cooling & ventilation, refrigeration and other) were estimated for the three building activity categories identified in the previous section (Figure 10).

The standard consumption factors for the first two groups (office and banking space & shopping space) were taken from published values developed specifically for those sectors in the USA CBECS (EIA, 2003: Table E6A). Applying the CBECS building activity specific standard consumption factors, ensured that the portion of energy consumption relating to heating and cooling would be appropriate to the activities being undertaken within the building. However it did not take account of the difference in average climate in the USA compared to Cape Town.

A standard consumption factor for the third category (other non-residential space) was taken from the published values developed for all commercial buildings in the USA located in the climate zone most similar to the City of Cape Town (USA EIA, 2003: Table E6A). Using the USA end use data based on climate zone ensured that the portion of energy consumption relating to heating and cooling would be appropriate to the City of Cape Town’s climate. However it was averaged for all commercial building activities including retail and offices, which had already been excluded from the Cape Town 'other' sample.

Neither of these approaches took account of other potential variations between USA and the City of Cape Town building stock such as the mean age and state of repair of buildings and building services, the efficiency and availability of appliances and building materials and the predominant fuels used.

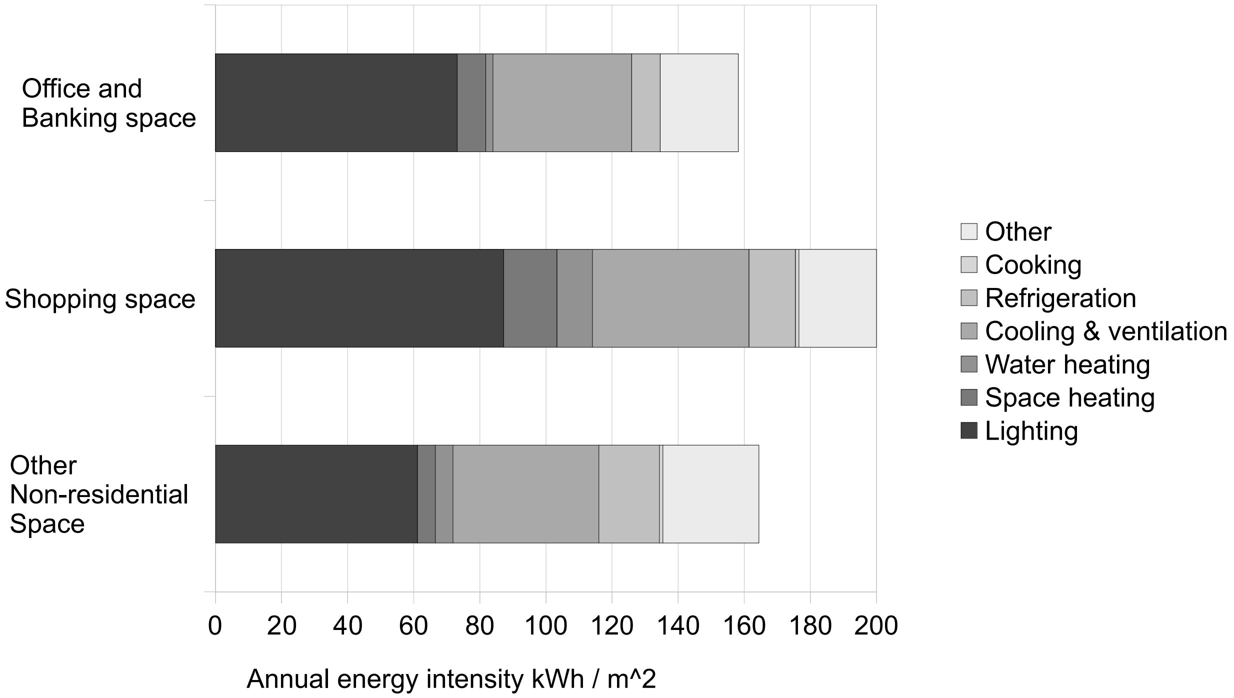

Figure 10: Electricity energy intensities by end use for three commercial building activity groupings. Source: USA EIA, 2003: Table E6A.

5.1.4.2 Other fuels

The USA end use data by fuel type could not be applied to the City of Cape Town as fuel use is considerably different in the two countries. For example most heating in the USA uses gas whereas in the City of Cape Town it is electric. This meant that to estimate the share of each fuel used by each end use for buildings in the City of Cape Town assumptions had to be made as to the end uses different fuels were used for.

The energy consumption by end use for other fuels was calculated from the data from the municipality air quality database. The buildings in the database were filtered into the appropriate commercial building activity groups. End uses were estimated by reviewing the comments in the database relating to energy consumption and considering the activities being undertaken within the buildings (Table 12).

Table 12: Summary of uses of different fuels by building activity & typical end use within the commercial sector in Cape Town.

Fuel	Main building activity using this fuel	End uses
Electricity	Retail, catering, accommodation, office, education, healthcare, other	Lighting, heating, cooling & ventilation, refrigeration, cooking & other (including office equipment and computers)
Diesel	Accommodation, office, education, healthcare, other	Other (includes generators and back up boilers)
Wood	Catering, other	Cooking & some aesthetic heating
Coal	Catering, healthcare	Heating & cooking
Paraffin	Accommodation, office, education	Heating
HFO	Education, healthcare	Other (includes generators and back up boilers)
LPG	Catering, education, healthcare	Heating & cooking

The overall typical end use for each building activity was calculated by weighting the standard electricity consumption factors by the proportion of floor area for each building activity (see Appendix 5: Energy consumption by end use).

5.2 Results

The typical end use benchmarks suggest that lighting and cooling & ventilation dominate energy consumption in the commercial sector in Cape Town with cooking contributing a negligible amount (Figure 11). Retail uses more energy for lighting than the office buildings (Figure 12).

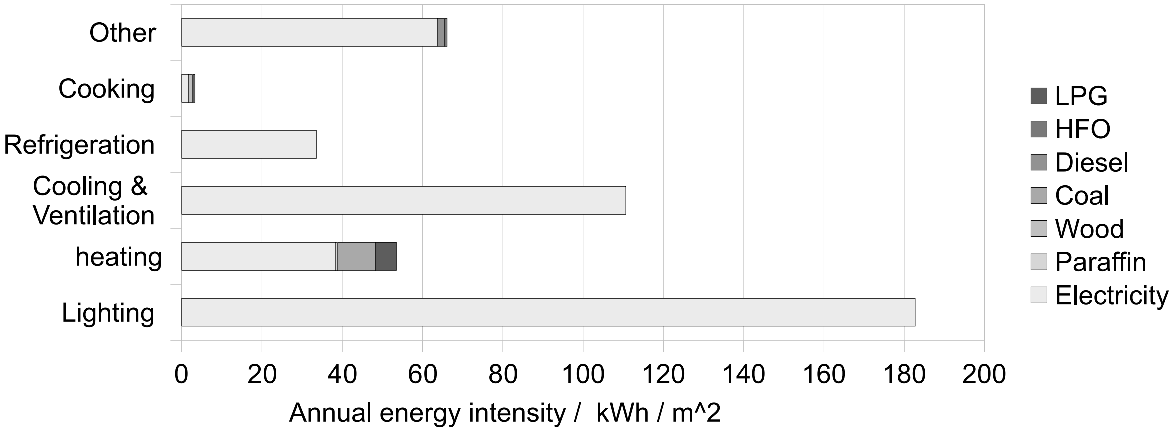

Figure 11: Typical energy consumption by end use and fuel type for the City of Cape Town commercial sector (see Appendix 5: Energy consumption by end use).

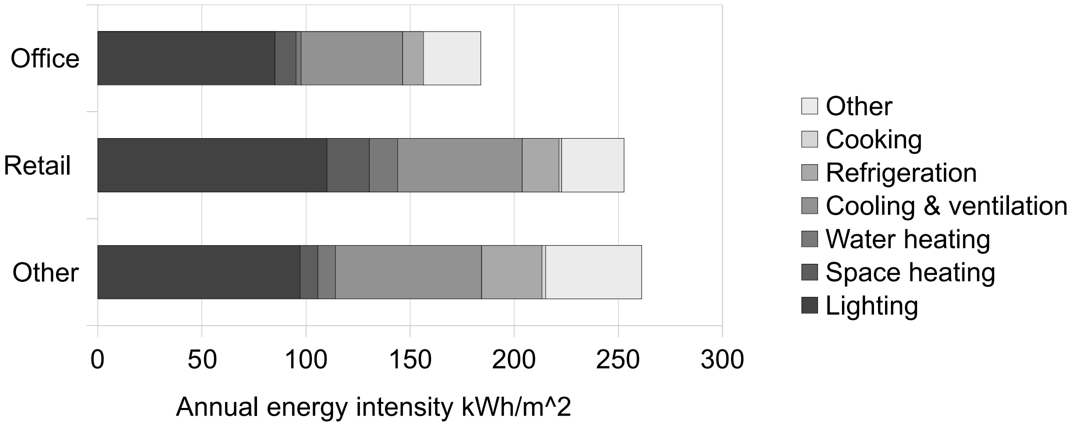

Figure 12: Benchmark by end use for office and retail buildings in Cape Town (see Appendix 5: Energy consumption by end use).

6 Cape Town benchmarks in context

The benchmarks generated in this study are compared with South African design targets to understand the difference between design aspirations and actual energy consumption, and with benchmarks from other countries to understand the performance of Cape Town buildings in a global context.

6.1 Methodology

The whole building benchmarks for offices and retail buildings developed in chapter 4 were compared with existing local benchmarks (DeVilliersLeach, 2008) and South African proposed national design targets (SABS, 2010).

The benchmarks were also compared with international benchmarks for similar building stocks from the UK (Field, 2008), USA (EIA, 2003; EPA, 2007: 7) and Australia (Bannister, 2005b: 18).

A comparable benchmark, with bedrooms as the energy-intensity indicator, was not available for hotels. For the 'other' commercial buildings category only the CBECS had published benchmarks for a similarly named category, however the building activities included in the CBECS data were different to those included in this study, rendering comparisons not meaningful.

In order to assess how the data collection method may influence the benchmark, the whole building office benchmark generated in this study (using existing data) was compared with the electricity benchmark generated using data collected using the survey approach by PJ Carew Consulting and the Cape Town Partnership in 2008 (DeVilliersLeach, 2008). The latter benchmark was generated from a sample that was smaller than this study, but contained buildings of a comparable size. The PJ Carew sample uses net useable floor area as the energy indicator. The gross floor area to net floor area factor suggested in the UK benchmark literature is 1.25 (Field, 2008). The reciprocal of this factor was applied to the floor areas of the buildings in the Cape Town sample and benchmarks were generated based on these new areas that allowed a more accurate comparison with the P J Carew sample.

To provide an indication of how far the buildings in this sample differed from the energy standards proposed for new buildings in South Africa, the benchmarks were compared against proposed national design targets (SABS, 2010). The design targets are based on energy consumption from all fuels, whereas the Cape Town benchmarks only consider electricity. To account for this the Cape Town benchmarks were adjusted to account for other fuels. This was based on the proportion of other fuels (4.3%) to electricity (95.7%) consumption in the commercial sector in Cape Town in 2007 (Appendix 5: Energy consumption by end use). The South African proposed building regulations also use net floor area as their energy indicator but define this as the rentable area rather than the useable area. A smaller gross floor area to net floor area factor of 1.1 was assumed based on the rule of thumb of allowing 10% floor area for services at design stage (Boushear, 2001: 6). The Cape Town benchmarks were recalculated accordingly.

In order to assess the performance of the Cape Town sample in a global context, the benchmarks were compared against average energy intensities from similar building stock datasets from the UK, USA and Australia. The UK has published median energy intensity values calculated from a number of surveys undertaken in the 1990's as national benchmarks (Field, 2008). National benchmark figures are not published by the USA or Australia, but national building stock datasets for a number of commercial building activities have been developed in these countries. The USA publishes mean energy intensities as part of their CBECS output data (USA EIA, 2003). The USA also publishes mean energy intensity values based on refined CBECS data, in the methodology of their Energystar energy rating system (USA EPA, 2007). Mean and a median energy intensities have been published for a sample of Australian buildings developed for the Australian buildings greenhouse gas rating (ABGR) (Bannister, 2005b:18). The ABGR system has now been superseded by NABERS energy (Aus DECCW, 2010) but details of the buildings stock samples used in NABERS energy are not publicly available.

The UK and USA use gross floor area as their energy indicator metric. Australia changed from gross floor area to net lettable area (NLA) for their energy rating scheme (then the ABGR) after a year of operation (Bannister, 2005b: 40).

All the samples, except USA Energystar, use site energy as the energy consumption metric. Site energy is defined as the energy supplied to a building in the form of gas, heat or electricity. Site energy does not take into account the losses incurred before the energy reaches the building. The USA Energystar rating system converts site energy to source energy values, incorporating transmission, delivery and production losses using national conversion factors. For this study these values were converted back to site values for ease of comparison (Ueno & Straube, 2010).

6.1.1 Adjustments to benchmarks

To allow a fair comparison between the Cape Town benchmarks and benchmarks from other countries, the energy intensity values from other countries were adjusted to account for difference in building characteristics outside the control of the building designers and operators, between those countries and Cape Town. In the case of the comparison with international benchmarks, sufficient data was available on all the datasets except the Australian data to account for variations in climate and variations in typical annual occupancies. An equation was developed to determine the adjusted international benchmark for the UK and USA samples, normalised to the Cape Town conditions.

The regression analysis approach to developing an adjustment equation could not be used on this sample for either occupancy or weather adjustments as insufficient data was available on the individual buildings in the Cape Town sample. The reference values approach, used in the UK (Field, 2008), was therefore used to develop an adjustment equation for weather and occupancy.

6.1.1.1 Weather adjustment

Reference annual cooling and heating degree day values (Table 67 & Appendix 6: Degree days) were calculated for Cape town that corresponded with the dates of the energy data in the sample (October 2006 to September 2007) (BizEE, 2010). A range of base-temperatures were used to correspond with the base temperatures used by the international benchmarks. These degree days were then compared with the reference degree-day values provided for the international benchmarks, where available, to scale the weather-dependent part of the benchmarks (heating & cooling loads) (Table 14a&b). The adjustments were calculated using the simple ratio-based weather normalisation of energy consumption method (BizEE Energy Lens, 2011).

6.1.1.2 Occupancy adjustment

The following occupancy characteristics were defined for offices and retail (Table 13);

- Reference occupancy hours for the listed building activity (Oref)
- Maximum (limiting) occupancy hours (Olim)
- Maximum percentage increase in energy consumption at the limiting occupancy hours (Emax)

The reference and limiting occupancy hours were estimated from typical operating hours in South Africa (see Appendix 7: Occupancy hours). The maximum percentage increase was taken from the UK benchmarks (Field, 2008: 17).

Table 13: Reference occupancy hours for South African offices and retail sector. * Percentage of non electricity fuel shown in brackets sourced from: (Field, 2008: table 1).

Building activity	**Definition of annual occupancy hours in this sector**	**Reference occupancy hours (Oref)**	**Maximum (limiting) occupancy hours (Olim)**	**Maximum percentage increase in energy consumption at the limiting occupancy hours* (Emax)**
Retail	Number of hours when the premises are fully open to customers according to published hours.	2228	3672	22%
Office	Number of hours when the recorded number of occupants exceeds 25% of the nominal maximum number.	1919	8760	107% (44%)

The following model was then used to determine the adjustment factor for occupancy, based on the UK approach (Field, 2008: 17).

a. If the international occupancy (Ob) was less than or equal to the Cape Town reference occupancy (Oref), the benchmark listed was used with no adjustment:	If Ob ≤ Oref then Aocc=0
b. If the international occupancy (Ob) was equal to or higher than the limiting occupancy (Olim) the benchmark was adjusted by applying the limiting percentage increase (Emax):	If Ob ≥ Olim then Aocc =Emax
c. For occupancy values in between these two extremes the percentage increase was interpolated on a pro-rata basis to obtain the adjusted benchmark. This assumes a linear dependence of energy consumption on the occupancy:	If Oref<Ob<Olim then Aocc = (Ob-Oref)/ (Olim-Oref)*(Emax)

6.1.2 *Adjusting the international benchmarks*

Where sufficient data was available (see Appendix 8: International benchmark data) the benchmarks from the UK and USA were adjusted to account for variations in the number of cooling and heating degree days and the number of hours of occupancy (Table 14). Insufficient data was available to adjust the Australian benchmarks.

Table 14: Adjustment of international benchmarks to normalise for Cape Town climate and typical annual occupancy, showing a. cooling adjustment b. heating adjustment c. occupancy adjustment d. overall adjusted benchmark. See Appendix 6: Degree days, Appendix 7: Occupancy hours and Appendix 8: International benchmark data for data sources.

a. Adjustment of cooling energy		**Offices**			**Retail**	
		UK	**USA energy star**	**USA CBECS (2003)**	**UK**	**USA CBECS (2003)**
BMI	International benchmark kWh/m2	215 (median)	316 (mean)	293 (mean)	272 (median)	288 (mean)
%clg	Proportion of annual electricity consumption used for cooling	7%	14%	14%	7%	15%
CDDb	Mean annual cooling degree days for international dataset	172 @ 18oC	642 @ 18oC	642 @ 18oC	172 @ 18oC	642 @ 18oC
CDDref	Reference cooling degree days Cape Town [8]	645.4 @ 18oC			645.4 @ 18oC	
A1	Adjustment of cooling energy = ((CDDi/ CDDref) – 1) * %clg * BMI	41.22	0.2	0.2	52.40	0.23

b. Adjustment of heating energy		**Office**			**Retail**	
		UK	**USA energy star**	**USA CBECS (2003)**	**UK**	**USA CBECS (2003)**
$\%_{htg}$	Proportion of annual electricity consumption used for heating	44%	5%	5%	44%	8%
HDD_b	Mean annual heating degree days for international dataset	2021@ 15.5oC	2450 @18oC	2450 @18oC	2021@ 15.5oC	2450 @18oC
HDD_{ref}	Reference heating degree days calculated for Cape Town	542.4 @ 18oC 997 @ 15.5oC			542.4 @ 18oC 997 @ 15.5oC	
A2	Adjustment of heating energy = ((HDDi/ HDDref) – 1)* %htg * BMI	-47.9	-12.3	-11.4	-60.64	-17.94

c. Adjustment of total energy due to occupancy hours		Office			Retail	
		UK	**USA energy star**	**USA CBECS (2003)**	**UK**	**USA CBECS (2003)**
Ob	Typical annual hours of occupancy for international dataset	2040	2760	2760	2448	unknown
Oref	Reference occupancy hours for Cape Town	1919			2228	
Olim	Maximum (limiting) occupancy hours	8760			3672	
Emax	Maximum percentage increase in energy consumption at the limiting occupancy hours	107%			22%	
A3	Adjustment of total energy - $O_{ref} < O_b < O_{lim}$ therefore A3= (Ob-Oref)/(Olim-Oref)*(Emax)	-4.07	-41.53	-38.55	-2.02	-

d. final adjusted benchmark	Office			Retail	
	UK	**USA energy star**	**USA CBECS (2003)**	**UK**	**USA CBECS (2003)**
Adjusted benchmark = BM+A1+A2+A3	204.42	262.14	243.32	261.75	270.30

6.2 Results

6.2.1 The South African context

The median electricity benchmark, from this sample adjusted for net floor area, was 22% less than the median electricity consumption calculated for 20 office buildings in central Cape Town in 2008 (DeVilliers-Leach, 2008) (Figure 13).

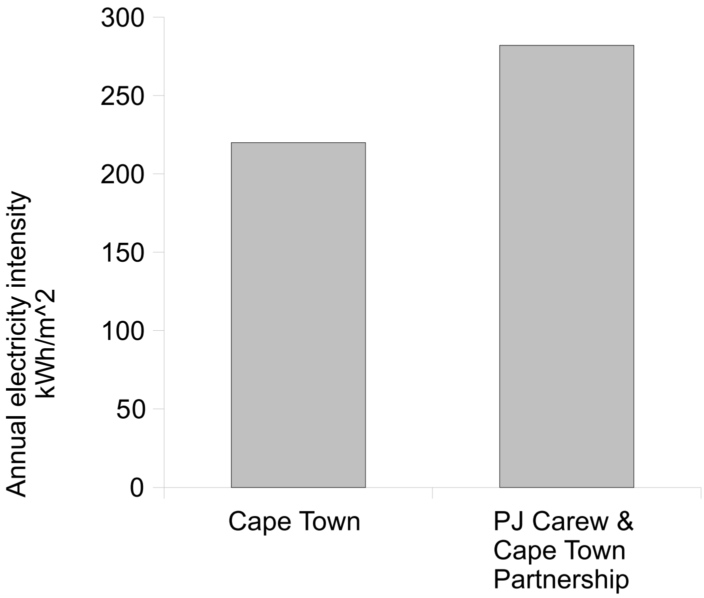

Figure 13: Comparison of the median electricity intensity for the Cape Town office sample (adjusted for net (useable) floor area), with the median electricity intensity of a sample of 20 office buildings in central Cape Town conducted by PJ Carew Consulting and the Cape Town Partnership.

The median energy intensity value for the Cape Town retail sample was 12% greater, and the Cape Town office sample was 8% greater, than national design targets calculated for the Cape Town region (Figure 14).

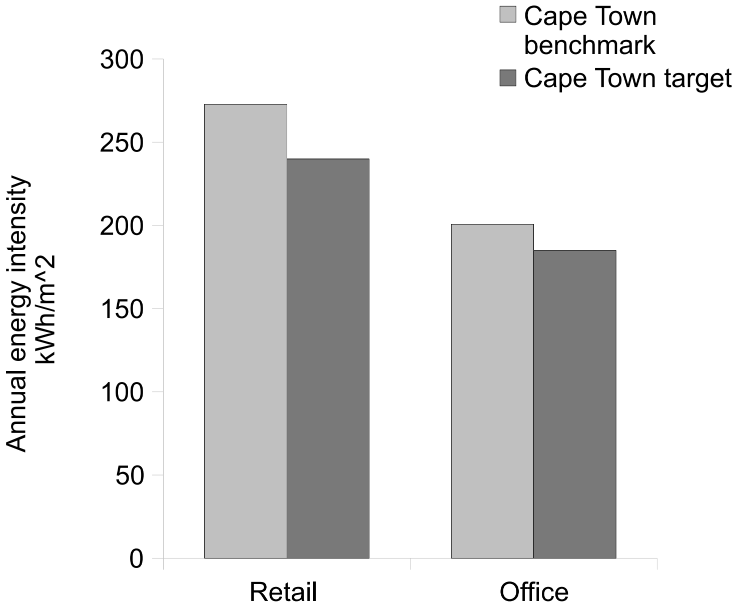

Figure 14: Comparison of the Cape Town benchmark (median energy intensity adjusted to account for all fuels and net (rentable) floor area), with South Africa proposed design targets for the Cape Town region.

6.2.2 The Global context

6.2.2.1 Retail

The Cape Town energy benchmark for retail (median) was compared with the UK benchmark (median) adjusted to account for the variations in mean heating and cooling degree days between the two samples. The Cape Town sample assumed the same occupancy levels as the UK benchmark and so no adjustment was necessary. The Cape Town benchmark was 3.5% less than the UK benchmark (Figure 15a).

The Cape Town mean energy intensity for the retail sample was compared with the USA CBECS mean value, adjusted to account for the variations in mean heating and cooling degree days between the two samples. Insufficient information was available to adjust the USA value for occupancy. The Cape Town value was 0.26% more than the USA value (Figure 15b).

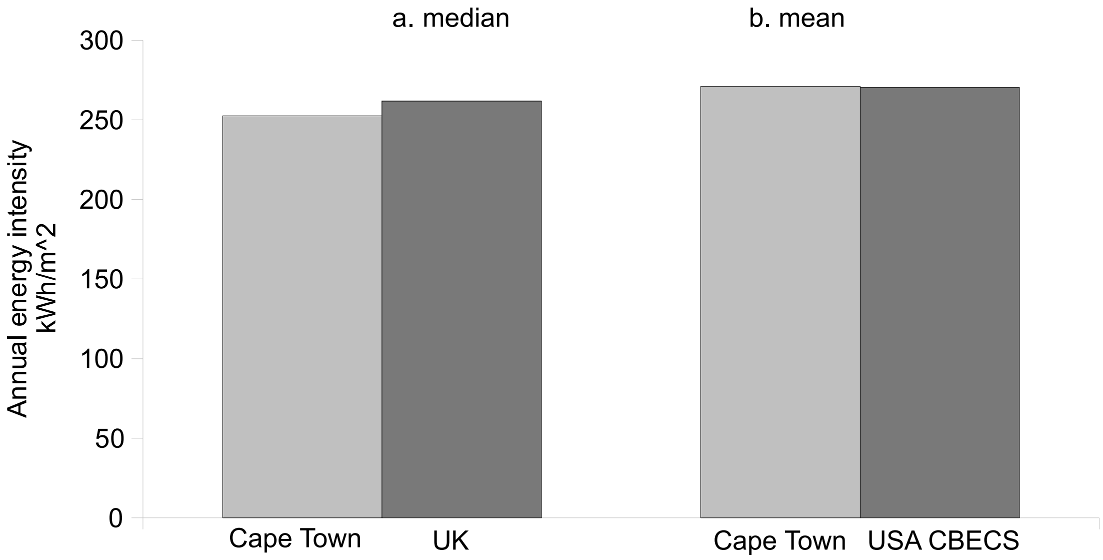

Figure 15: Comparison of a. the median energy intensity for Cape Town retail with median UK benchmark and b. the mean energy intensity for Cape Town retail with the USA mean value.

6.2.2.2 Offices

The Cape Town energy benchmark for offices (median) was compared with the UK benchmark (median) adjusted to account for the variations in mean heating degree days between the two samples. The Cape Town benchmark was 10% less than the UK benchmark (Figure 16a).

The Cape Town mean energy intensity for offices was compared with the USA mean values for offices, adjusted to account for the variations in mean heating and cooling degree days and annual hours of occupancy between the samples. The Cape Town benchmark was 19% less than the USA CBECS value and 25% less than the USA Energystar value (Figure 16b).

Insufficient data was available to adjust the Australian values for variations in mean weather or occupancy and so comparisons were not considered useful.

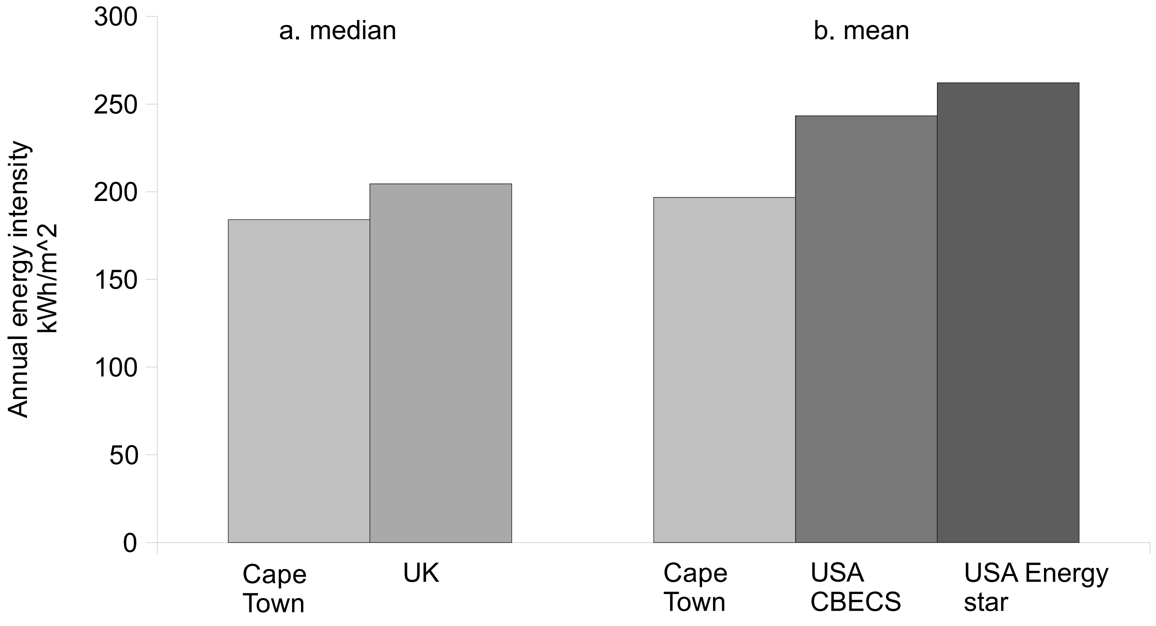

Figure 16: Comparison of a. the median benchmark for Cape Town offices with the UK median benchmark and b. the mean energy intensity for Cape Town offices with the USA mean values.

7 Discussion

Data limitations and data gaps encountered during this study are presented and the extent to which they influenced the outcome of the benchmarking process is discussed. Opportunities have been identified where South Africa can leapfrog traditional data collection techniques. Recommendations have been made for the improvement of the data collection process for Cape Town. Finally conclusions have been drawn in the context of how the benchmarks generated in this study might be used and how they might impact the key stakeholders identified in chapter 1.

Although the Cape Town retail benchmark was very similar to benchmarks for similar building stocks in the UK and USA, the benchmark for Cape Town office buildings was considerably less. The office benchmark generated in this study was also considerably less than that generated from a similar sample of 20 Cape Town office buildings undertaken in 2008. Caution should be exercised before assuming that this indicates that office buildings in Cape Town are particularly energy efficient, as several other possible explanations exist. The sample may not be sufficiently representative of commercial buildings in Cape Town. Further, the buildings may use less energy because they provide a lesser service than similar buildings in other countries, or some of the buildings in the sample may have been only partially occupied. It is also possible that the municipality data contains inaccuracies.

The comparison of the benchmarks with the national design targets for new buildings suggested that 40% of the retail buildings and 44% of the office buildings in the sample already perform better than the proposed design targets for new buildings. This was a surprising result considering that the computer simulations model ideal environmental performance standards, usually resulting in lesser values than empirical data (Bannister, 2009). With the knowledge that existing South African buildings have historically not been subjected to minimum environmental performance standards [13], these results could reflect that some commercial buildings in Cape Town are achieving best practice energy performance by compromising the quality of the internal environment, rather than from operating efficiently. Studies have suggested that increasing environmental performance standards does not necessarily lead to increased energy intensity (Moorlach & Hughes, 2010; Piani, 1995). If reductions in energy consumption can go hand in hand with improvements in internal environmental comfort, the proposed South African design targets could potentiality be more ambitious than those currently proposed.

In many instances additional detailed data on the buildings in the sample were required to be able to make robust conclusions, highlighting data limitations and data gaps in this sample. These data limitations and data gaps are discussed in the following sections.

7.1 Sample characteristics

7.1.1 Sample size

A small sample size can result in an uncharacteristic representation of the overall population under consideration. Although the Cape Town samples were smaller than the samples used to develop national datasets in other countries (e.g. Australia offices n=215 (Bannister, 2005b: Table 1), USA CBECS offices n=824 (USA EIA, 2003: Table A1), the Cape Town samples contained a relatively large proportion (1% for retail, 1.5% for offices) of the total Cape Town retail and office building stock. In comparison the retail and office samples in the USA CBECS, represent 0.1% of the national building stock (see Appendix 8: International benchmark data). Comparable data for the national building stock of Australia were not available.

7.1.2 Sample bias

The mean gross floor area of the buildings in the Cape Town office sample (12,641m^2) was considerably larger than the mean floor area value of the USA energy star sample (3,843m^2) (EPA, 2007: Table 2) and the average of the Australian sample (7,460m^2) (Bannister, 2005b). The Australian sample was noted as being biased towards large central business district type office buildings (Bannister, 2005b). This suggests that this sample could have a similar bias.

The mean floor area values can be misleading as they can be distorted by just a few buildings that lie at the extreme ends of the scale (e.g. a few very large buildings will result in a high mean). The median provides a potentially more representative value of the typical floor area of the buildings in the sample, in the case of the Cape Town office sample the median floor area was 6198m^2. It was not specified whether the Australian average was the mean or median value. The USA CBECS value was the mean and so may be distorted by a few small buildings included in the sample.

A bias towards larger buildings was also suggested by the origin of the Cape Town sample; the top 75% of energy consumers on the municipality large power user tariffs. Although larger buildings have higher absolute energy consumption values, they have been shown to have smaller energy intensities than smaller buildings due to variables such as occupancy density, which tend to be greater in smaller buildings (Wilkinson & Reed, 2006). This could mean that the Cape Town sample bias towards large buildings could result in a lower benchmark than if a more representative sample had been used.

7.2 Data quality

7.2.1 *Electricity data*

Sales data is collected primarily for billing purposes and therefore actual energy consumption for a given period may not always be accurate, particularly in the case of pre-paid customers who may have bought electricity for more than one year. As benchmarks are presented as an annual energy intensity, this could result in annual benchmarks being greater than they actually are. In the electricity sales sample, used to generate the whole building benchmarks, this was not a concern as there were no prepaid tariffs included in the sample. For the end-use benchmarks prepaid electricity accounted for 0.57% of the total municipality commercial electricity sales and so it was considered that prepaid electricity that was used outside of the dates considered in the study would be insignificant.

Electricity sales data is collected based on defined geographic areas which do not necessarily agree with the area selected for study. For example Eskom work from historic boundaries based on the municipality boundaries that existed when their transmission network was developed and which have since changed. Consequently Eskom were unable to disaggregate sales data by the current geographical boundary of the City of Cape Town municipality. The areas where the boundary was not clear were in low density rural areas on the outskirts of the City. These areas are therefore not likely to influence the overall commercial-sector electricity consumption considerably and so an approximation to the City of Cape Town boundary line was considered acceptable. This was not an issue for the whole building benchmarks which only used data provided by the municipality.

7.2.2 *Fuels other than electricity*

For both the whole building benchmarks and the end use benchmarks, the key source of energy-consumption data not relating to electricity was the municipality air quality departments annual survey of registered industrial and commercial fuel burning appliances. This dataset was limited as it only including registered commercial fuel burning appliances and not smaller unregistered appliances. The accuracy of these data was less reliable than the electricity data as it only provided an energy consumption estimate for a single month which had to then be extrapolated to represent a whole year. In reality, fuel use may vary considerably month on month depending on variables such as temperature and patterns of occupancy.

7.2.3 Floor area data

Floor area was used as the energy-intensity indicator for most building activities in this study (except hotels). This meant that determining the floor area was critical for determining the final energy intensity in most instances.

For the whole building benchmarks, floor area data was required for each building within the sample. The valuations on-line data base was used to extract these data, however a number of limitations of this database were identified. Some entries gave unrealistic floor areas due to values having been entered more than once in the database. Furthermore the database was incomplete. Only 38% of the commercial buildings identified in the sample could be found in the on-line database, despite having ERF numbers for all the sample. This dramatically decreased the number of buildings that could be included in the final sample. It was not clear why some buildings were not found in the database, if there was a reason that they were excluded based on characteristics that also had an impact on energy consumption, then this could potentially add further bias to the final sample.

A further limitation was that using the municipality datasets to identify floor-area data for individual buildings exposed the consumers' identities. Exposing consumer identity when analysing energy consumption was shown in the literature to be one of the barriers to obtaining energy- consumption data in buildings due to concerns about privacy and confidentiality (DME, 2003: 36; Moffatt 2004: 16). Although the final benchmarks do not contain the consumer-identity information, the raw data needs to remain a confidential resource when using these methods, unless declaring annual energy consumption or carbon emissions becomes mandatory, as is being proposed and implemented in certain sectors in a number of countries including South Africa (see Carbon Disclosure Project, 2011).

For the end use benchmarks, floor area for the entire commercial sector in Cape Town was required.

Collecting floor area data on individual buildings via the valuations on-line database was found to be unrealistic for a large number of buildings due to the time required to extract the data. As an alternative, floor area data, provided for all buildings completed since 1993 (Stats SA, 2010) was used. However these data were more suited to estimating the commercial floor area in larger geographic regions such as province or for the whole of South Africa, rather than by City, and a number of assumptions had to be used in combination with these data to determine a floor area for commercial buildings in Cape Town.

7.2.4 Disaggregation by sector and building activity

Disaggregating energy data by sector and building activity results in more relevant energy benchmarks. Electricity data was easier to disaggregate by sector than by building activity. Municipality total electricity sales data for customers on the LPU tariffs was the only electricity data source not disaggregated by sector in the annual overview provided by the suppliers (Ross, 2008). However it was possible to estimate this fairly accurately based on the supplementary detailed data provided by the municipality for 75% of these customers (CCT, 2007a).

Municipality customers on the SPU tariffs and Eskom sales data could not be disaggregated by building activity. Eskom could not provide data disaggregated by building activity and would not provide raw data with customer details from which this information might be ascertained, due to their customer privacy policy. This resulted in an estimate of total electricity consumption by sector for Cape Town and the development of a second smaller dataset containing energy consumption for a sample of buildings on the municipality LPU tariffs aggregated by commercial building activity.

A limitation to the LPU sample provided by the municipality was that many of the customers were registered as a body corporate, property fund or trust and in these cases the activity undertaken within the building was not clear. Using the ERF number and entering this in the on-line valuations database further identified the building activity of a number of these unknown customers. However, as experienced with the collection of floor area data, there were still a number of the customers that did not appear in the valuation on-line database. The total number of customers for which a sector could not be identified amounted to 20% of the SAP sample.

7.3 Detailed building data

7.3.1 Energy consumption data by end use

Understanding energy consumption by end use helps understand the paradigm of energy consumption for different building types and helps identify the reasons for variations in energy consumption between buildings. A significant data gap in South Africa is building data relating to energy consumption by end use. For this study estimations of electricity consumption by end use in Cape Town were based on those made for similar stocks in the USA. These estimates were developed in the USA using statistical methods and modelling rather than from monitoring real buildings (EIA, 2009a), without data from real buildings these estimates may not account for trends in poor controls or management, specific to different end uses in South Africa.

The majority of the world's building stock, including the USA stock, does not have sub-metering for each end use meaning that end use data is time consuming and expensive to extract. The lack of data worldwide on accurate energy consumption by end use in buildings is being addressed with the introduction of mandatory sub-metering in many countries (e.g. Jones, 2006). However these regulations will initially only impact new buildings and renovations via building regulations, consequently robust datasets based on sub-metering of buildings, are still several years away.

Although the CBECS data provided a useful guide for South African buildings there is no substitute for accurate data on South African buildings. While undertaking this research two opportunities for SA to obtain the data without undertaking expensive additional surveys were identified;

Firstly building activity specific end uses could be modelled for a variety of building activities in South Africa using a similar approach as the USA CBECS, which estimates end use consumption based on computer simulations. This modelling could take account of characteristics specific to South Africa such as climate, fuel use and types of systems typically used in buildings in South Africa.

Secondly real energy data for specific end uses could be extracted from Eskom DSM projects. The Eskom DSM initiative requires before and after surveys to be undertaken on buildings to demonstrate the energy savings made by the energy efficiency interventions funded by the scheme. The interventions tend to focus on one particular end use, such as lighting or air conditioning. If Eskom collected these data in a format that could be used to extract the mean energy intensity of various end uses for specific building activities throughout South Africa, this could provide an indication of the proportion of energy used for specific end uses. As the Eskom DSM surveys are already required to be undertaken in a consistent manner, this could provide a rigorous approach to collecting end use data in South Africa.

7.3.2 Building characteristics

Reviewing international benchmarks suggested that the most accurate approach to normalising the energy benchmarks was by developing a regression equation for the sample. This allowed various relationships between energy consumption and building characteristics for different building activities to be explored and adjusted for. To undertake this exercise, building characteristic data are required for a sufficiently large and unbiased sample of buildings to enable the relationship between the characteristic and energy consumption to be statistically described with the necessary certainty.

In this study, data on a number of potential building characteristics (e.g. occupancy hours, number of PCs) was not available for each building in the sample. This limited the opportunity for normalisation through using a regression approach. The literature review indicated that collecting this type of data would be time-consuming as it would require detailed surveys of buildings, but would result in more relevant operational ratings for buildings. The USA CBECS is a notable example of where these data have been collected.

7.3.3 Environmental Performance

To be able to understand energy efficiency of the national building stock, environmental performance needs to be included in the energy-performance comparison. Data on the performance of South Africa's commercial building stock, in terms of provision of adequate heating, cooling, lighting and ventilation levels, was not available. In other countries this type of data is often identified by establishing the year of construction of a building and assuming a level of performance based on the building regulation minimum performance requirements of that time. Although year of construction data was available for some of the commercial buildings in Cape Town from the valuation on-line database, these data were not useful because energy related building regulations do not exist in South Africa. For energy performance certificates, environmental performance could be addressed by including minimum standards for certain services such as lighting levels and ventilation levels, which need to be met before a rating can be calculated and a certificate issued.

7.4 Data gaps

Data gaps were defined as areas where data that was necessary for generating benchmarks or improving their usefulness was not collected in any form in South Africa (Table 15). The key data gaps found when generating the whole building benchmarks for commercial buildings in Cape Town were building characteristics for each building in the sample and any measure of environmental performance (comfort). For the end use benchmarks, empirical data on energy consumption by end use and aggregated floor area data for commercial buildings in the City of Cape Town were lacking.

Table 15: Summary of where data on building stock and energy consumption in commercial buildings is currently collected in South Africa and where the data gaps lie.

Building stock data	**Resources in the City of Cape Town**
Electricity Consumption	ESKOM sales. Municipality electricity sales department.
Other fuels consumption	Municipality air quality database – only includes consumers with registered appliances.
Energy consumption by end use	**DATA GAP**
Floor area data for individual buildings	Municipality valuation department on line database – not complete.
Floor area data for South Africa commercial sector	Floor area data available for buildings completed from 1993 to 2007. Prior to 1993 none available.
Floor area data for the City of Cape Town commercial sector	**DATA GAP**
Building characteristics	**DATA GAP**
Degree day data	Airport weather data available from 2004 for 4 of 6 climatic regions in South Africa. Incomplete data available for 2 remaining regions.
Year of construction	Municipality valuation department on line database.
Performance data (internal environmental quality)	**DATA GAP**

7.5 Opportunities in South Africa

This study demonstrates that the structure of electricity use and distribution in South Africa has the potential to provide a relatively straight forward access to energy records. Electricity dominates energy consumption in commercial buildings in Cape Town, which currently has two electricity suppliers; Eskom and the municipality. This contrasts with other countries, which often have more than one dominant fuel and can have many independent energy suppliers e.g. the UK has over 70 suppliers of electricity and gas (Energylinx, n d).

The capabilities of GIS present an opportunity for improving and co-ordinating building related data collection in South Africa, as they are specifically designed to capture, store, analyse, manage and present data linked to geographical locations. Encouragingly, in a country where resource and training can be an issue, the six metropolitan municipalities in South Africa have already embraced GIS and are exploring the capabilities of this system to store and analyse data in a number of contexts. Following the example from the UK NDBS project (Bruhns, Steadman, & Herring, 2000), a national building stock database could be developed for South Africa using GIS that co-ordinates the data collected by the municipality valuations departments and the electricity billing departments. However this study highlighted that these data would need to be supplemented with data that can currently only be obtained via bespoke surveys, such as annual hours of occupancy and internal environmental conditions, and that detailed data on fuels other than electricity and energy consumption by end use is lacking in South Africa.

7.6 Recommendations

To improve data access (including other fuels data), the following key steps are recommended;

1. *Co-ordinate databases:* Co-ordinate the descriptors used to identify the building activities within the various parties that collect building related data. Preferably these would be based on an internationally accepted definition of each building activity such as the North American Industry Classification System, (NAICS) (US Census Bureau, 1997). Assign the same customer/building ID to electricity sales data, valuations data and other fuels data such that databases can be interlinked.

2. *Ensure that data access is not limited by consumer privacy issues:* Establish a protocol to preserve customer identity, e.g. ensure that published data is anonymous but that privacy agreements can be made to allow the data to be analysed prior to publication or mandate compulsory reporting of annual electricity consumption.

3. *Ensure high quality data collection:* Ensure floor area data is calculated in a consistent manner using standard national guidelines (e.g. South Africa Property Owners Association (SAPOA, 2005)). Develop quality assurance procedures for collecting billing data and floor area data.

4. *Establish a central database for detailed surveys on small samples of buildings:* The detailed data required for understanding and normalising energy benchmarks can be collected in two ways, either by survey of each individual building in the sample, or by taking average values representative of the national building stock and applying these to the sample (see TM46 normalisation process (Field, 2008)). A potential resource that could be exploited to provide these data is the surveys undertaken as part of the Eskom demand side management initiative. A hierarchical collection of data sets will then have been created ranging from those providing little information about the majority of commercial premises in South Africa (the valuation-office data and electricity sales data) to those containing very detailed data on just a few premises (the Eskom data). Inference methods can then be used to make reliable extrapolations from the detailed information to the stock as a whole. This would become a very powerful database for South Africa and would position South Africa at the forefront of building energy-data collection.

7.7 Conclusions

The purpose of this research was to produce energy benchmarks for a variety of building activities within the commercial sector in Cape Town and in doing so test the hypothesis that sufficient existing data exists in South Africa to be able to achieve this aim.

This has been achieved by identifying established data collection and analysis approaches used internationally, and applying these to data for a sample of buildings in the City of Cape Town obtained from existing data collection systems. Data limitations and gaps have been identified and recommendations to improve data collection have been made. This has provided invaluable information needed for future work to generate benchmarks representative of a larger population of commercial buildings in South Africa.

The results from this research provide whole building energy benchmarks for the specific building activity categories of retail, office and business hotels and a final generic category 'other' for all other commercial buildings. The benchmarks represent the typical energy intensity of the sample. The sample was biased towards larger buildings and was focussed on electricity consumption. This bias suggests that the benchmarks would need to be used with caution by building owners and designers if using them to consider the performance of their own buildings or designs. The analysis indicated that these benchmarks are likely to be less than if they had been generated from a more representative sample that included smaller buildings.

The sample used in this study suggests that around 40% of office and retail buildings in the sample already meet the minimum standards proposed for new buildings. This highlights the importance of understanding the performance of the existing building stock and suggests that further research should be undertaken on the existing commercial building stock in South Africa to identify whether this result is as a consequence of poor internal environment, efficient operation or poor quality data.

During the last few months of completion of this dissertation the Green Building Council of South Africa issued a request for proposals for a building energy & water performance benchmarking tool, specifically for existing buildings, to rate their performance against a 'national average'. This research provides the preliminary study for this tool including a summary of current international best practice and an example of existing data collection processes in South Africa that can be used to create the initial dataset from which benchmarks can be generated.

A review of international best practice relating to the energy benchmarking process for the commercial building sector identified the USA CBECS as an exemplar and well documented data collection process and the USA EnergyStar rating tool as a statistically rigorous approach to normalising the energy intensities and rating buildings. However the research also identified that the USA CBECS method of data collection was time consuming and hence costly to undertake, and relied heavily on the cooperation of survey participants. An alternative approach to data collection for generating whole building benchmarks was presented in this study. By coordinating existing datasets a reasonable sample of buildings was obtained and potential to increase the sample size was identified. South Africa is in a unique position to take advantage of this approach due to its current energy supply structure.

In addition to whole building benchmarks, end use benchmarks were developed for retail, offices and all other buildings. These were based on standard electricity consumption factors taken from estimates made for similar USA building stocks and standard other fuels consumption factors developed from data for the City of Cape Town. These results suggested that lighting contributed the most to energy consumption in the City of Cape Town followed by cooling and ventilation.

During the process of generating end use benchmarks, this study provided a comprehensive base line year of energy consumption for the commercial sector in the City of Cape Town for the year 2007/2008 (see Appendix 5: Energy consumption by end use). This has already been used by the municipality to develop their most recent energy scenarios for Cape Town project (ERC, SEA, 2011).

The results of this research provide an invaluable starting point to understanding the paradigm of energy consumption in the commercial sector in South Africa. The research indicates that the retail sector has a higher energy intensity than the office sector in the Cape Town sample, suggesting that the retail sector could be a focus for future energy efficiency programmes. Furthermore, estimates of energy consumption by end use suggest that lighting dominates electricity consumption in both retail and offices in the Cape Town sample and that cooling and ventilation was the next greatest use for electricity (section 5.2) suggesting that these particular end uses should be addressed first. These results confirm that Eskom's well established campaign for improving lighting efficiency (Eskom, 2008a:9)was well grounded.

A number of recommendations were identified relating to data-collection improvement. In particular the end use estimates could be made more applicable to South African buildings with the inclusion of data from existing Eskom DSM projects. Furthermore aligning the categories in which electricity sales data was recorded with building activities was identified as being critical if these data sources were to be used to develop a similar building stock database on a national scale. This study relied considerably on data collected by the City of Cape Town municipality and discusses the many aspects of these data and provides recommendations on improvements that should be incorporated into the current streamlining of the municipality's data collection process.

The overall objective was met by generating benchmarks from a clearly defined sample dataset whilst providing well-documented assumptions and access to the original technical references. Although the benchmarks generated in this study should be treated with caution due to the quality of data, this research still provides useful and much needed benchmarks for stakeholders in the City of Cape Town, providing that the caveats outlined in this study are taken into account. The results have been demonstrated to be useful to a variety of stakeholders nationwide to realise more energy efficient buildings and provides valuable information needed for future development of benchmarks in South Africa.

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Appendix 1: Electricity consumption (SAP sample)

Table 16: Summary of City of Cape Town municipality electricity sales for the top 75% of consumers on the LPU tariffs disaggregated by sector and commercial building activity. Source: CCT, 2007a.

Building activity	Number of Customers	Energy consumption kWh/annum	Consumption as a percentage of the total annual commercial electricity consumption in Cape Town in 2007/2008
Commercial - Retail	139	458,742,065	12.6%
Commercial - Catering	10	3,874,064	0.1%
Commercial - Accommodation	33	67,447,061	1.9%
Commercial - Office	99	260,344,232	7.2%
Commercial - Education	17	98,339,032	2.7%
Commercial - Healthcare	36	100,657,292	2.8%
Commercial - Other	60	96,619,110	2.7%
Commercial – mixed use	1	191,213	0.01%
Commercial - Warehouse	27	95,996,890	2.6%
Commercial total	422	1,182,210,958	32.5%
Unknown	255	391,618,300	-
Industry	350	985,059,159	-
Public Sector	149	276,299,321	-
Residential	21	75,271,132	-
Agriculture	3	1,720,712	-
Total LPU sample	1,200	2,912,179,583	-

Table 17: List of retail premises in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	1000717711	28494414	7534	3782.11	1951
2	1000761794	22113901	6459	3423.73	1999
3	1000159815	3199000	6515	491.02	1990
4	1000245863	1131480	2311	489.61	2006
5	1001482105	3422920	7613	449.62	-
6	1001593829	2066694.4	4888	422.81	2005
7	1000512339	1382860	3600	384.13	1996
8	1000720985	1188811.2	3148	377.64	1989
9	1000636864	612245	1658	369.27	1997
10	1001537370	147453.58	405	364.08	1990
11	1000135432	1808142	5000	361.63	2006
12	1000699037	3012500	8399	358.67	2006
13	1000782211	3577950	10067	355.41	1990
14	1000716070	3616440	10350	349.41	2001
15	1001894222	1173740	3427	342.5	2000
16	1000203188	1104097	3466	318.55	1999
17	1001303356	4008390	13053	307.09	1970
18	1000774075	17160660	62061	276.51	1975
19	1000059976	1633636	5954	274.38	1980
20	1001656705	2760220	10378	265.97	2004

	SAP REF	Consumption kWh/annum	Extent of property m²	Energy intensity kWh/m²	Year built
21	1000485788	1752090	6618	264.75	1996
22	1000260428	330482	1355	243.9	1989
23	1001268157	6028710	25159	239.62	1990
24	1001647393	1572666.25	6838	229.99	2001
25	1001693822	3720460	17480	212.84	1994
26	1001315987	3635820	17212	211.24	1982
27	1000139870	1103746	5371	205.5	2004
28	1000169900	2597590	13490.6	192.55	1970
29	1001154012	3558090	18481	192.53	1986
30	1000451194	1295710	7130	181.73	1970
31	1001635835	407120	2368	171.93	-
32	1000794569	439801.6	2606	168.77	-
33	1001404319	1136016	7064	160.82	1999
34	1001548949	292515	1902	153.79	1988
35	1001203783	2601304	17212	151.13	1982
36	1000462674	223959	1553	144.21	1955
37	1000539312	1533040	10682	143.52	0
38	1000451194	3812840	29238	130.41	1947
39	1000592292	531930	5018	106	-
40	1000717711	1699163.2	16461	103.22	2002

	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
41	1000109516	70380	686	102.59	1990
42	1000236354	275543	2686	102.58	1995
43	1000924207	260400	2742	94.97	1973
44	1000201493	8514900	93478	91.09	1988
45	1001316105	1290630	15000	86.04	1972
46	1001739332	11446560	151974	75.32	1970
47	1001566977	74442	1957	38.04	0
48	1000148011	44700	1643	27.21	1985
49	1001578690	119710	4525	26.46	2005
50	1001485676	46140	4417	10.45	1960
51	1001885989	28231	2746	10.28	-
52	1001919468	4728	1564	3.02	1950

Table 18: List of catering establishments in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	Type	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	Food Service	1001035574	1005288	602	1670	1951
2	Food Service	1000227307	634900	697	911	1997

Table 19: List of hotels in SAP LPU sample that had information on number of bed rooms (analytical filter has not been applied to this list).

	Type	SAP REF	Consumption kWh/annum	Number of bed rooms	Energy intensity kWh/m^2
1	Hotel	1001302744	14943920	483	30939.79
2	Hotel	1001107847	7298790	368	19833.67
3	Hotel	1001157960	5835360	546	10687.47
4	Hotel	1001316110	5781960	410	14102.34
5	Hotel	1001111016	5743890	201	28576.57
6	Hotel	1001502126	4575800	202	22652.48
7	Hotel	1000964166	3519520	207	17002.51
8	Hotel	1000109453	1811520	198	9149.09
9	Hotel	1001171178	1584720	162	9782.22
10	Hotel	1001072914	1361620	106	12845.47
11	Hotel	1000492583	473720	92	5149.13
12	Hotel	1001891916	14402.4	131	109.94

Table 20: List of accommodation (other than hotels) in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	Type	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	Retirement home	1000956176	1341665	7893	169.98	1990
2	Retirement home	1000103014	229440	2410	95.2	1970
3	Retirement home	1000154424	215200	2618	82.2	1988

Table 21: List of office in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	1001166591	1249	1766860	1414.62	1991
2	1001060759	2308	1638180	709.78	1957
3	1001171144	8654	5650740	652.96	1959
4	1000897293	17289	9302520	538.06	1994
5	1000683023	2402	1005359	418.55	-
6	1001171141	12502	4683870	374.65	-
7	1000697540	835	303501	363.47	1977
8	1000824019	7298	1983144	271.74	1984
9	1001316118	17000	4498120	264.6	1995
10	1000583917	1747	424212	242.82	1971
11	1001157947	36034	8206320	227.74	0
12	1000492733	4395	963100	219.14	1980
13	1001613927	1869	405800	217.12	1986
14	1001324308	6696	1443552	215.58	1957
15	1001157984	5979	1256786	210.2	1984
16	1000492733	2334	472625	202.5	1983
17	1001171183	11216	2270875	202.47	1953
18	1001043619	7133	1388520	194.66	1950
19	1000552400	3307	642010	194.14	2004

	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
20	1000663526	7073	1366490	193.2	2000
21	1000123793	738	141840	192.2	1980
22	1001667630	2501	477545	190.94	1996
23	1001002768	1216	227516.4	187.1	1950
24	1001210849	13031	2396370	183.9	1970
25	1001323191	31325	5517560	176.14	2000
26	1001433252	6198	1086076	175.23	1959
27	1000942810	42583	6891975	161.85	1925
28	1001323058	16437	2593080	157.76	2001
29	1000727082	21959	3424950	155.97	1992
30	1001888288	3284	504011	153.47	1978
31	1001269859	16064	2438683.2	151.81	2000
32	1000638278	1746	254620	145.83	2004
33	1001561035	10926	1587195	145.27	-
34	1001519043	2565	369010	143.86	1932
35	1000774671	5556	791945	142.54	1925
36	1001202205	2170	299280	137.92	1973
37	1001425807	4107	566060	137.83	1996
38	1001296605	42737	5859420	137.1	1966
39	1000972387	35802	4846800	135.38	1961

	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
40	1000865856	5241	658512	125.65	1940
41	1001495579	16182	2031680	125.55	1995
42	1000487454	5282	630470	119.36	1979
43	1001072902	28822	3259490	113.09	1964
44	1001608116	4024	443890	110.31	1996
45	1000929815	70000	7337640	104.82	2003
46	1001691254	7986	761630	95.37	2004
47	1001498964	13251	1261560	95.2	1994
48	1000499108	1690	159079	94.13	1964
49	1000824926	7000	611288.4	87.33	1920
50	1000092896	1709	136400	79.81	1980
51	1000154443	1952	149591	76.63	2001
52	1001181584	8157	466296	57.17	1958
53	1001002330	5408	289278	53.49	1959
54	1000972601	34306	1762590	51.38	1963
55	1001326312	13781	664430	48.21	1959
56	1001661603	1601	75410	47.1	1999
57	1000807214	10318	480700	46.59	-
58	1000636274	28011	1258800	44.94	-
59	1001838401	9157	247160	26.99	2007
60	1001974446	2250	25501.8	11.33	1960

Table 22: List of Education premises from SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	Type	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	Education	1001173595	45388880	1965	23098.67	1925
2	Education	1000544114	16937000	114158	148.36	-
3	Education	1000975456	3075320	114909	26.76	-

Table 23: List of healthcare premises in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	Type	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	Healthcare	1000139655	1039440	7800	133.26	1939
2	Healthcare	1001129601	933033.6	4767	195.73	1971
3	Healthcare	1000465373	918520	6483	141.68	2000
4	Healthcare	1000567954	632070	1371	461.03	1990
5	Healthcare	1000227869	304884	1682	181.26	1995
6	Healthcare	1000489267	88884	376	236.39	1980
7	Healthcare	1001107475	13074870	43155	302.97	1970
8	Healthcare	1000680533	1491850	5562	268.22	1985
9	Healthcare	1000045738	566895.97	3601	157.43	1985

Table 24: List of 'other' commercial premises in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	Type	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	Telecommunications	1000745675	2078100	4864	427.24	1964
2	Telecommunications	1000745675	1792245.6	1653	1084.24	1933
3	Community facilities	1001366934	934230	2523	370.29	2004
4	Telecommunications	1000745675	501650.4	653	768.22	1925
5	Telecommunications	1000745675	411067.2	1226	335.29	1998
6	Telecommunications	1000711711	182687	315	579.96	1990
7	Telecommunications	1000120068	173100	515	336.12	1995
8	Telecommunications	1000745675	120206	456	263.61	1990
9	Telecommunications	1000570533	29036	749	38.77	1960
10	Telecommunications	1000711616	26701300	11656	2290.78	1970
11	Telecommunications	1000745675	9667360	21449	450.71	1925
12	Telecommunications	1000745675	8129610	14934	544.37	1970
13	Telecommunications	1000711711	197884	930	212.78	1940

Table 25: List of warehouse buildings in SAP LPU sample that had floor areas in valuations database (analytical filter has not been applied to this list).

	SAP REF	Consumption kWh/annum	Extent of property m^2	Energy intensity kWh/m^2	Year built
1	1001087377	1423330	8795	161.83	1968
2	1001677788	1387240	2570	539.78	1980
3	1001115927	778107.6	12818	60.7	1925
4	1001019969	344020	1283	268.14	1991
5	1000730651	6879840	23240	296.03	1980

Appendix 2: Other fuels consumption

Table 26: Summary of average monthly fuel consumption by commercial customers registered in municipality air quality database 2006.

	Fuel	**Paraffin**	**Wood**	**Coal**	**Diesel**	**HFO**	**LPG**
	Units	Litres per month	bag per month	kg per month	Litres per month	Litres per month	m^3 per month
Sector	**Number of consumers**	**6**	**135**	**4**	**57**	**2**	**6**
Retail	**0**	0	0	0	0	0	0
Catering	**143**	0	14739	400	1500	0	620
Accommodation	**14**	33800	0	0	12510.5	0	222
Office	**31**	1850	0	0	76241	0	0
Warehouse & Storage	**4**	25000	0	0	4265	0	0
Education	**8**	300	0	0	872	23000	605292
Healthcare	**12**	0	0	560068	13020	2200	172.8
Other	**23**	0	18	220200	15020	14000	150
Total	***235***	*67550*	*14757*	*780668*	*123428.5*	*39200*	*606456.8*

Table 27: Summary of fuel consumption by commercial customers registered in municipality air quality database 2006 in GJ/ annum (for conversion factors see Appendix 9: Useful conversion factors).

GJ/annum	**Number of consumers**	**Paraffin**	**Wood**	**Coal**	**Diesel**	**HFO**	**LPG**	**Total GJ/annum**
Retail	**0**	0	0	0	0	0	0	0
Catering	**143**	0	33605	149	666	0	186	34606
Accommodation	**14**	14602	0	0	5555	0	67	20223
Office	**31**	799	0	0	33851	0	0	34650
Warehouse & Storage	**4**	10800	0	0	1894	0	0	12694
Education	**8**	130	0	0	387	11040	181588	193144
Healthcare	**12**	0	0	208345	5781	1056	52	215234
Other	**23**	2851	41	81914	6669	6720	45	98241
Total	***235***	29182	33646	290408	54802	18816	181937	608791
Total excluding warehouses	***231***	18382	33646	290408	52909	18816	181937	596098

Appendix 3: Electricity consumption (City of Cape Town)

3.1 City of Cape Town Municipality: Electricity sales data Cape Town (Ross, 2008)

Table 28: Municipality sales to customers on Small Power User (SPU) tariffs (kWh) April 2007- March 2008.

kWh	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	*Total*
Public Sector	9 662 008	11 334 611	6 497 659	9 932 904	9 545 323	9 189 023	9 802 014	8 287 106	9 563 236	11 266 960	9 174 686	9 119 808	113 375 340
Residential	309,507,956	337,179,167	388,495,474	374,100,024	395,573,967	368,161,774	334,426,409	318,993,258	313,554,487	312,072,480	287,973,044	309,048,258	4,049,086,297
Commercial	125,578,411	118,259,366	115,448,263	118,810,953	124,625,639	134,728,111	112,174,342	121,535,826	118,737,636	120,123,711	112,429,917	201,400,397	1,523,852,570

Table 29: Municipality sales to customers on Large Power User (LPU) tariffs (kWh) April 2007- March 2008.

kWh	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	*Total*
Public Sector	13 986 599	10 236 461	7 133 210	11 130 808	7 025 171	11 448 829	7 309 131	10 401 431	7 747 879	10 852 267	12 246 532	9 617 399	119 135 718
All other sectors	361,208,869	311,728,026	321,270,117	327,364,312	323,139,442	321,311,512	317,225,452	294,403,456	330,446,128	329,717,315	352,027,263	274,366,299	3,864,208,191

Table 30: Municipality total sales (kWh) April 2007- March 2008.

kWh	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	*Total*
Public Sector	23,648,607	21,571,072	13,630,870	21,063,712	16,570,494	20,637,852	17,111,146	18,688,538	17,311,115	22,119,227	21,421,218	18,737,207	232,511,057
Residential	309,507,956	337,179,167	388,495,474	374,100,024	395,573,967	368,161,774	334,426,409	318,993,258	313,554,487	312,072,480	287,973,044	309,048,258	4,049,086,297
Commercial SPU	125,578,411	118,259,366	115,448,263	118,810,953	124,625,639	134,728,111	112,174,342	121,535,826	118,737,636	120,123,711	112,429,917	201,400,397	1,523,852,570
Other LPU	361,208,869	311,728,026	321,270,117	327,364,312	323,139,442	321,311,512	317,225,452	294,403,456	330,446,128	329,717,315	352,027,263	274,366,299	3,864,208,191

Table 31: Municipality number of customers on Small Power User (SPU) tariffs April 2007- March 2008.

	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	*Total*
Public Sector	2 296	2 321	2 301	2 305	2 342	2 323	2 307	2 288	2 251	2 292	2 254	1 896	2 342
Residential	515,738	524,720	531,050	535,413	531,773	525,502	525,587	525,410	523,111	521,882	522,368	526,357	535 413
Commercial	27,149	27,573	27,127	23,981	27,439	27,299	27,366	27,496	26,751	27,178	27,368	26,683	27 573

Table 32: Municipality number of customers on Large Power User (LPU) tariffs April 2007- March 2008.

kWh	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	*Total*
Public Sector	78	92	91	92	93	97	95	95	91	91	90	76	97
All other sectors	1,546	1,536	1,536	1,620	1,559	1,563	1,563	1,559	1,545	1,553	1,549	1,308	1 620

Table 33: Municipality total number of customers April 2007- March 2008.

kWh	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	*Total*
Public Sector	2,374	2,413	2,392	2,397	2,435	2,420	2,402	2,383	2,342	2,383	2,344	1,972	2,439
Residential	515,738	524,720	531,050	535,413	531,773	525,502	525,587	525,410	523,111	521,882	522,368	526,357	535,413
Commercial SPU	27,149	27,573	27,127	23,981	27,439	27,299	27,366	27,496	26,751	27,178	27,368	26,683	27 573
Other LPU	1,546	1,536	1,536	1,620	1,559	1,563	1,563	1,559	1,545	1,553	1,549	1,308	1 620

3.2 Eskom - Electricity sales data Cape Town 2007/2008 (Lennox & Redelinghuys, 2008)

Table 34: Eskom sales to customers on Small Power User (SPU) tariffs (kWh) April 2007- March 2008.

kWh	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	***Total***
Agricultural	967 062	1 023 072	747 140	1 163 978	1 050 762	1 101 711	821 007	1 009 721	871 511	1 027 356	1 083 232	1 011 426	*11 877 979*
Commercial	12 009 221	9 193 977	10 731 593	11 413 759	11 111 837	14 154 305	10 938 555	12 039 721	10 903 211	10 262 860	11 050 301	12 250 465	*136 059 803*
Industrial	1 482 080	1 353 518	1 449 494	1 731 454	1 622 189	2 428 573	2 302 274	2 169 943	2 109 864	1 191 262	1 857 117	1 941 064	*21 638 831*
Residential	30 182 840	28 690 585	37 636 869	34 608 733	34 170 579	38 325 357	28 584 159	34 211 931	29 208 868	29 241 691	28 177 260	31 901 749	*384 940 619*

Table 35: Eskom sales to customers on Large Power User (LPU) tariffs (kWh) April 2007- March 2008.

kWh	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	***Total***
Agricultural	4,681,546	3,747,953	3,857,081	3,610,931	4,051,239	3,778,629	3,647,408	3,987,038	4,269,965	4,557,083	5,045,778	4,902,666	*50 137 317*
Commercial	38,913,664	36,529,798	39,044,345	38,036,684	38,388,990	38,526,026	37,291,972	38,457,918	43,465,301	36,109,986	40,141,206	39,305,687	*464 211 577*
Industrial	29,124,151	28,709,486	31,642,813	30,730,070	31,363,650	31,781,217	30,940,864	31,456,148	26,971,006	21,600,830	30,310,229	29,567,029	*354 197 493*
Residential	466,497	488,115	554,396	560,821	648,291	610,687	534,283	524,610	444,826	419,757	492,983	496,443	*6 241 709*

Table 36: Eskom total sales (kWh) April 2007- March 2008.

kWh	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	***Total***
Agricultural	5,648,608	4,771,025	4,604,221	4,774,909	5,102,001	4,880,340	4,468,415	4,996,759	5,141,476	5,584,439	6,129,010	5,914,092	*62 015 296*
Commercial	50,922,885	45,723,775	49,775,938	49,450,443	49,500,827	52,680,331	48,230,527	50,497,639	54,368,512	46,372,846	51,191,507	51,556,152	*600 271 380*
Industrial	30,606,231	30,063,004	33,092,307	32,461,524	32,985,839	34,209,790	33,243,138	33,626,091	29,080,870	22,792,092	32,167,346	31,508,093	*375 836 324*
Residential	30,649,337	29,178,700	38,191,265	35,169,554	34,818,870	38,936,044	29,118,442	34,736,541	29,653,694	29,661,448	28,670,243	32,398,192	*391 182 328*
% of electricity sold to all municipalities in Western Cape during 2007/08						75.9%							
% of electricity sold to City of Cape Town during 2007/08						34.6%							

3.3 Calculation to determine the ratio of industry to commercial sales in municipality electricity LPU sales data

Table 37: Sales data from CCT municipality SAP sample of top 1200 LPU consumers 2006/2007. Warehouse and storage is included in industrial.

Sector	**Consumption**	**Customers**	**Proportion of total**
Unknown	391,618,300	255	14.86%
Industrial	1,081,056,049	377	41.01%
Residential	75,271,132	21	2.86%
Agriculture	1,720,712	3	0.07%
Commercial	1,086,214,069	395	41.20%
Total	2,635,880,261	1,051	100%

Table 38: Comparing LPU data from CCT municipality total sales data (April 2007- March 2008) and CCT municipality top 1200 LPU sales (SAP) (October 2006 – September 2007) (excluding Public Sector).

	Calculation	**kWh/annum**	**Customers**
Total munic LPU	Table 30; Other LPU	3,864,208,191	1620
Total SAP LPU	Table 16; Total – Public Sector	2,635,880,261	1,051
Remaining LPU's	Total munic LPU – Total SAP LPU	1,228,327,930	569

Table 39: Remaining LPU sales not included in CCT municipality SAP sample, split in same proportions as LPU sales in SAP sample.

Sector	**Calculation**	**kWh/annum**	**Customers**
Unknown	Table 39; remaining LPU * Table 38; unknown proportion of Total	182,495,276	138
Industry	Table 39; remaining LPU * Table 38; industry proportion of Total	503,775,289	204
Residential	Table 39; remaining LPU * Table 38; residential proportion of Total	35,076,568	11
Agriculture	Table 39; remaining LPU * Table 38; agricultural proportion of Total	801,857	2
Commercial	Table 39; remaining LPU * Table 38; commercial proportion of Total	506,178,941	214
Total		1,228,327,930	569

3.4 Summary of commercial electricity sales in the City of Cape Town (April 2007- March 2008)

Table 40: Summary of electricity sales by City of Cape Town municipality in the commercial sector in the City of Cape Town April 2007- March 2008.

City of Cape Town municipality	Calculation	kWh/annum	GJ/annum	% share	Customers
Large Power Users	Table 37; commercial + Table 39; commercial	1,592,393,010	5,738,825	51%	609
Small Power Users	Table 28; commercial	1,523,852,570	5,491,812	49%	27573
Total	Sum of above	3,116,245,580	11,230,637	100%	28182

Table 41: Summary of electricity sales by Eskom in the commercial sector in the City of Cape Town April 2007- March 2008.

Eskom	Calculation	kWh/annum	GJ/annum	% share	Customers
Large Power Users	Table 35; commercial total	464,211,577	1,672,972	77%	
Small Power Users	Table 34; commercial total	136,059,803	-	23%	
Total	Table 36; commercial total	600,271,380	2,163,318	100%	5429[3]

Table 42: Summary of electricity sales in the commercial sector in the City of Cape Town April 2007- March 2008.

Supplier	Calculation	kWh/annum	GJ/annum	% share	Customers
City of Cape Town municipality	Table 40; total	3,116,245,579	10,932,318	84%	28468
Eskom	Table 41; total	600,271,380	2,163,318	16%	5633
Total	Sum of above	3,716,516, 960	13,393,955	100%	33,610

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[3] Extrapolated from number of municipality consumers

Appendix 4: Floor area estimate (City of Cape Town)

Table 43: Sum of floor area of commercial buildings reported completed to municipalities in South Africa by type of building 1995 -2007 (Statistics South Africa (Stats SA), 2009).

	Total floor area completed between 1995-2007	**As a % of South Africa**
Western Cape	*3.81*	*13.2%*
South Africa	*28.95*	

Table 44: Population estimates. Source: (Statistics South Africa (Stats SA), 2001).

	Population 2001	**As a % of South Africa**	**As a % of Western Cape**
Cape Town	2,892,243	6.5%	63.9%
Western Cape	4,524,335	10%	
South Africa	44,819,770		

Table 45: Floor area estimates for the commercial sector for South Africa, the Western Cape and Cape Town. *South Africa 1994 base value sourced from

(DeVilliers, 2000:18). ** Western Cape 1994 base value was calculated as 13.2% of South Africa base value (see Table 43). South Africa and Western Cape annual growth from 1994 sourced from (Stats SA, 2009). Cape Town values calculated as being 63.9% of Western Cape value (see Table 44).

Year	South Africa buildings completed / million square meters	South Africa total floor area estimate / million square meters	Western Cape buildings completed / million square meters	Western Cape total floor area estimate / million square meters	Cape Town / million square meters
1994		68.9*	0.31	9.07**	5.8
1995	2.27	71.17	0.28	9.39	6
1996	3.02	74.19	0.31	9.67	6.18
1997	2.85	77.04	0.3	9.98	6.38
1998	2.52	79.56	0.34	10.27	6.57
1999	2.55	82.12	0.34	10.62	6.79
2000	2.29	84.41	0.33	10.95	7
2001	1.55	85.96	0.28	11.29	7.22
2002	1.47	87.44	0.19	11.57	7.4
2003	1.43	88.86	0.21	11.76	7.52
2004	1.78	90.64	0.26	11.97	7.65
2005	2.21	92.85	0.24	12.23	7.82
2006	2.54	95.38	0.41	12.47	7.97
2007	2.46	97.85	0.31	12.89	8.24

Appendix 5: Energy consumption by end use

5.1 Summary of energy consumption in the commercial sector in Cape Town by fuel and end use (April 2007- March 2008).

Table 46: Energy consumption in the commercial sector in Cape Town by fuel April 2007- March 2008. (excluding warehouses).

	Electricity	**Paraffin**	**Wood**	**Coal**	**Diesel**	**HFO**	**LPG**	**Total**
Total GJ/annum	13,393,955	18,382	33,646	290,408	52,909	18,816	181,937	13,990,053
As a share of total	95.74%	0.13%	0.24%	2.08%	0.38%	0.13%	1.30%	100%

Table 47: Energy consumption in the commercial sector in Cape Town by fuel and end use April 2007- March 2008.

	Lighting	**Heating**	**Cooling & ventilation**	**Refrigeration**	**Cooking**	**Other**	***Total***	***Total***
Fuel	*MJ*	*MJ*	*MJ*	*MJ*	*MJ*	*MJ*	*MJ*	*kWh*
Electricity	5,683	1,191	3,441	1,043	52	1,984	13,394	3,271
Paraffin	0	18	0	0	0	0	18	5
Wood	0	0	0	0	34	0	34	9
Coal	0	290	0	0	0	0	290	81
Diesel	0	0	0	0	0	53	53	15
HFO	0	0	0	0	0	19	19	5
LPG	0	164	0	0	18	0	182	51
Total MJ	5,683	1,663	3,441	1,043	104	2,056	13,394	3,886
Total kWh	1,579	462	956	290	29	571	3,886	

Table 48: Energy intensity in the commercial sector in Cape Town by fuel and end use April 2007- March 2008.

Fuel	**Lighting** MJ/m²	**Heating** MJ/m²	**Cooling & ventilation** MJ/m²	**Refrigeration** MJ/m²	**Cooking** MJ/m²	***Other*** *MJ/m²*	***Total*** *MJ/m²*	***Total*** *kWh/m²*
Electricity	690	145	418	127	6	241	1,625	451.52
Paraffin	0	2.23	0	0	0	0	2.23	0.62
Wood	0	0	0	0	4.08	0	4.08	1.13
Coal	0	35.22	0	0	0	0	35.24	9.79
Diesel	0	0	0	0	0	6.421	6.42	1.78
HFO	0	0	0	0	0	2.283	2.28	0.63
LPG	0	19.85	0	0	2.23	0	22.08	6.13
Total MJ/m²	690	202	418	127	13	249	1,698	471.62
Total kWh/m²	191.58	56.08	115.99	35.16	3.51	69.3	471.62	

Table 49: Energy shares in the commercial sector in Cape Town by fuel and end use April 2007- March 2008.

Fuel	**Lighting**	**Heating**	**Cooling & ventilation**	**Refrigeration**	**Cooking**	**Other**	**Total**
Electricity	42%	9%	26%	8%		15%	100%
Paraffin		100%					100%
Wood					100%		100%
Coal		100%					100%
Diesel						100%	100%
HFO						100%	100%
LPG		90%			10%		100%
Total	41%	12%	25%	7%	1%	15%	100%

5.2 Calculation of share of electricity consumption by end use in the commercial sector

Table 50: Floor area built between 1993 and 2009 divided between three commercial sub-sectors (source: Stats SA, 2009).

Commercial sector	**Share of floor space since 1993**
Office and banking space	38%
Shopping space	28%
Other non-residential space	34%
Total	100%

Table 51: Electrical energy-intensity by end use and sub-sector (source: USA EIA, 2003: Table E6A).

Commercial sector	**Lighting** MJ/m^2	**Space heating** MJ/m^2	**Water heating** MJ/m^2	**Cooling & ventilation** MJ/m^2	**Refrigeration** MJ/m^2	**Cooking** MJ/m^2	**Other** MJ/m^2
Office and banking space (USA EIA, 2003: Table E6A Office)	264	31	8	151	31	0	85
Shopping space (USA EIA, 2003: Table E6A Mercentile)	314	58	39	171	50	4	85
Other non-residential space (USA EIA, 2003: Table E6A Under 2000 CDD & Fewer than 4000 HDD)	220	19	19	159	66	4	105

Table 52: Electrical share by end use and sub-sector (source: USA EIA, 2003: Table E6A).

Commercial sector	**Lighting**	**Space heating**	**Water heating**	**Cooling & ventilation**	**Refrigeration**	**Cooking**	**Other**
Office and banking space	46.26%	5.44%	1.36%	26.53%	5.44%	0.00%	14.97%
Shopping space	43.55%	8.06%	5.38%	23.66%	6.99%	0.54%	11.83%
Other non-residential space	37.16%	3.28%	3.28%	26.84%	11.13%	0.66%	17.67%

Table 53: Weighted electrical energy intensity calculated by end use and sub-sector.

Commercial sector	**Lighting** MJ/m^2	**Space heating** MJ/m^2	**Water heating** MJ/m^2	**Cooling & ventilation** MJ/m^2	**Refrigeration** MJ/m^2	**Cooking** MJ/m^2	**Other** MJ/m^2	**Total** MJ/m^2
Office and banking space	100	12	3	57	12	0	32	217
Shopping space	88	16	11	48	14	1	24	203
Other non-residential space	74	7	7	54	22	1	35	200
Weighted average	263.0	34.7	20.4	159.2	48.3	2.4	91.8	619.8
Weighted average as share of total	42.4%	5.6%	3.3%	25.7%	7.8%	0.4%	14.8%	1.0

5.3 Calculation of share of other fuels consumption by end use in the commercial sector

Table 54: Summary of other fuels consumption by end use.

Fuel	**Heating**	**Cooking**	**Other**	**Heating**	**Cooking**	**Other**	**Total**
	% of fuel used			GJ	GJ	GJ	*GJ*
Paraffin	100%			15530.4			*15530.4*
Wood	0.12%	99.88%		41.04	33604.9		*33645.9*
Coal	99.93%	0.07%		208345.3	148.8		*208494.1*
Diesel			100%			52242.59	*52242.6*
HFO			100%			12096	*12096*
LPG	89.90%	10.10%		163454.76	18370.68		*181825.44*

Table 55: Paraffin consumption by building activity and end use.

Building activity	Heating	Cooking	Other	Heating	Cooking	Other
	% of Paraffin used			GJ	GJ	GJ
Retail						
Catering						
Accommodation	100%			14601.6		
Office	100%			799.2		
Education	100%			129.6		
Healthcare						
Other						
Total				*15530.4*		

Table 56: Wood consumption by building activity and end use.

Building activity	Heating	Cooking	Other	Heating	Cooking	Other
	% of wood used			GJ	GJ	GJ
Retail						
Catering		100%			33604.92	
Accommodation						
Office						
Education						
Healthcare						
Other	100%			41.04		
Total				41.04	33604.92	

Table 57: Coal consumption by building activity and end use.

Building activity	Heating	Cooking	Other	Heating	Cooking	Other
	% of coal used			GJ	GJ	GJ
Retail						
Catering		100%			148.8	
Accommodation						
Office						
Education						
Healthcare	100%			208345.3		
Other						
Total				208345.3	148.8	0

Table 58: Diesel consumption by building activity and end use.

Building activity	Heating	Cooking	Other	Heating	Cooking	Other
	% of diesel used			GJ	GJ	GJ
Retail						
Catering						
Accommodation			100%			5554.66
Office			100%			33851
Education			100%			387.17
Healthcare			100%			5780.8
Other			100%			6668.9
Total						52242.6

Table 59: HFO consumption by building activity and end use.

Building activity	Heating	Cooking	Other	Heating	Cooking	Other
	% of HFO used			GJ	GJ	GJ
Retail						
Catering						
Accommodation						
Office						
Education			100%			11040
Healthcare			100%			1056
Other						
Total						12096

Table 60: LPG consumption by building activity and end use

Building activity	Heating	Cooking	Other	Heating	Cooking	Other
	% of HFO used			GJ	GJ	GJ
Retail						
Catering		100%			186	
Accommodation						
Office						
Education	90%	10%		163428.84	18158.76	
Healthcare	50%	50%		25.92	25.92	
Other						
Total				163454.76	18370.68	

Appendix 6: Degree days

6.1 Cape Town

Table 61: Number of Fahrenheit-based heating and cooling degree days in Cape Town (base temp 65°F) April 2007- March 2008 to compare with CBECS climate categories for determining standard end use factors in end use benchmarks.

Month starting	Heating degree days	Cooling degree days
April 2007	103.32	109.26
May 2007	196.92	45.9
June 2007	291.78	11.16
July 2007	325.98	11.16
August 2007	296.1	10.98
Sept 2007	221.4	24.84
Oct 2007	122.76	95.22
Nov 2007	94.32	59.76
Dec 2007	34.56	194.04
Jan 2007	20.16	205.2
Feb 2007	18	194.4
March 2007	42.48	185.58
Total	**1767.78**	**1147.5**
USA CBECS (USA EIA, 2003: Table E6A)	**<4000**	**<2000**

Table 62: Number of celsius-based heating and cooling degree days in Cape Town October 2006 – September 2007 used for adjusting international benchmarks.

Month starting	**Heating degree days**	**Heating degree days**	**Cooling degree days**
Base temp	**18oC**	**15.5oC**	**18oC**
October 2006	41	76.6	35.4
November 2006	15.4	43.5	66.3
December 2006	4.1	19.6	83.9
January 2007	7.2	15.8	139.6
February 2007	2.3	13.8	105.7
March 2007	11.5	29.9	88.2
April 2007	26.4	59	70.1
May 2007	60.3	102.9	25.5
June 2007	86.5	153.1	6.2
July 2007	112.6	174.6	5
August 2007	103.9	178.2	7.3
September 2007	71.2	130	12.2
Total	**542.4**	**997**	**645.4**

6.2 UK

Table 63: Degree day data for the UK. Note that cooling degree days were not published with the UK benchmarks.

Base temperature	**15.5ºC**	**18ºC**
Heating degree days - 10 year simple average to Dec 2007 (Field, 2008)	2021	-
Cooling degree days – 5 year average (2006 to 2010) (BizEE, 2010)	-	172

6.3 USA

Table 64: Degree days data from USA EnergyStar converted to units comparable with Cape Town benchmarks. Source: (EPA, 2007: Table 2). Since a temperature difference of 1°C is equivalent to a temperature difference of 1.8°F, Fahrenheit-based degree days are 1.8 times bigger than their equivalent Celsius-based degree days.

Base temperature	**65ºF**	**18ºC**
Heating degree days	4411	2451
Cooling degree days	1157	643

6.4 South Africa degree day look up tables

In order for the benchmarks generated in this study to be applicable to other areas of south Africa they would need to be adjusted to account for variations in climate between locations in South Africa. The following tables have been included to enable such adjustments to be made.

Table 65: Details of weather stations used to develop degree day look up table for whole building benchmarks. The weather stations cover four of the five climatic regions defined in the South African draft national standard, energy usage in buildings (SANS 10400-XA). A suitable weather station was not available for the hot interior climatic region.

Weather station ID	type	Location	Lat	Long	Months	Years	Climatic region
FAJS	airport	Johannesburg	28.23E	26.13S	79	6.58	Cold interior
FAUP	airport	Upington	21.27E	28.40S	79	6.58	Arid interior
FABL	airport	Bloemfontein	26.30E	29.10S	79	6.58	Cold interior
FACT	airport	Cape Town	18.60E	33.98S	79	6.58	Temperate coastal
FAPE	airport	Port Elizabeth	25.60E	33.98S	79	6.58	Temperate coastal
IGAUTENG8	other	Moreleta Park, Pretoria (9mi/16km)	29.8E	25.84S	57	4.75	Temperate interior
IKZNRICH2	other	Richards Bay (1mi/3km)	32.07E	28.76S	26	2.17	Sub tropical coastal

Table 66: Annual cooling degree days for a selection of years and locations in South Africa (Base Temp 18ºC).

Cooling Degree days		**Year**						
Location	**Climate**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Mean**
Johannesburg	cold interior	448	639	533	672	612	580	581
Upington	arid interior	1639	1794	1701	1842	1824	1795	1766
Bloemfontein	cold interior	773	872	688	849	881	794	810
Cape Town	temperate coastal	520	616	620	657	614	662	615
Port Elizabeth	temperate coastal	611	622	640	700	622	605	633
Pretoria	temperate interior			915	961	876	804	889
Richards Bay	sub tropical coastal						1543	1543
Mean		798	909	850	947	905	969	896

Table 67: Annual heating degree days for a selection of years and locations in South Africa (Base Temp 18ºC). Richards bay value was excluded from mean as unlikely that heating would be used for such a small number of degree days.

Heating Degree Days		**Year**						
Location	**Climate**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Mean**
Johannesburg	cold interior	1280	1107	1345	1211	1122	1204	1212
Upington	arid interior	869	934	1042	990	891	867	932
Bloemfontein	cold interior	1621	1596	1861	1875	1631	1740	1721
Cape Town	temperate coastal	950	1066	962	994	947	844	961
Port Elizabeth	temperate coastal	796	814	806	737	751	692	766
Pretoria	temperate interior			859	1065	1019	1084	1007
Richards Bay	sub tropical coastal						192	192
Mean		1103	1103	1145	1145	1060	1071	1104

Appendix 7: Occupancy hours (South Africa)

Table 68: Typical working hours for retail and offices in South Africa. Public holidays data sourced from: South Africa Government, 2011a. Office working hours based on 39 hour week, retail working hours based on 45 hour week.

Billing month	Number of days in the billing month	Number of Saturdays	Number of Sundays	Number of Public holidays	Total number of working days (office)	Total number of working hours (office)	Total number of working days (retail)	Total number of working hours (retail)
October 2006	28	4	4	0	20	24	156	180
November 2006	32	5	5	0	22	27	171.6	202.5
December 2006	32	5	4	4	19	23	148.2	172.5
January 2007	31	5	4	1	21	25	163.8	187.5
February 2007	29	4	4	0	21	25	163.8	187.5
March 2007	29	4	4	2	19	23	148.2	172.5
April 2007	32	5	5	3	19	24	148.2	180
May 2007	29	4	4	1	20	24	156	180
June 2007	30	4	4	1	21	25	163.8	187.5
July 2007	29	4	4	0	21	25	163.8	187.5
August 2007	33	5	5	1	22	27	171.6	202.5
September 2007	31	5	4	1	21	25	163.8	187.5
Total	365						**1919**	**2228**

Appendix 8: International benchmark data

8.1 CBECS data

Table 69: Estimation of CBECS sample sizes calculated by assuming that the number of buildings in each category presented in the CBECS tables were directly proportional to the number of buildings in the original sample. *Source: (USA EIA, 2003: Table A1).** Source: (USA EIA, 2009c).

Building activity	Number of buildings in USA*	Number of buildings sampled	Sample size relative to total population
Retail	657,000	705	0.11%
Office	824,000	884	0.11%
Other	79,000	85	0.11%
Total	4,859,000	5215**	0.11%

Table 70: Mean energy-intensity data from USA CBECS converted to units comparable with Cape Town benchmarks. Source: (USA EIA, 2003: Table C3A).

Building activity	Thousand BTU per square foot	kWh/ft^2	kWh/m^2
Retail	91300	27	288
Office	92900	27	293
Other	164400	48	519

Table 71: Mean floor area data from USA CBECS converted to units comparable with Cape Town benchmarks. Source: (USA EIA, 2003: table A1).

Building activity	Mean area per building / ft^{2}*	Mean area per building / m^{2}
Retail	17000	1579
Office	14800	1375
Other	21900	2035

8.2 EnergyStar data

Table 72: Energy star sample size (EPA, 2007: Table 1).

Office	Sample size	Total population (US national office building stock from CBECS data)	Sample size relative to total population
USA (EnergyStar)	498	824,000	0.06%

Table 73: Mean floor area data for USA EnergyStar converted to units comparable with Cape Town benchmarks. Source: (EPA, 2007: Table 2).

Office	Natural log of ft^{2}	ft^{2}	m^{2}
Mean floor area	9.535	13836	3843

Table 74: Operating hours data from USA EnergyStar converted to units comparable with Cape Town benchmarks. Source: (EPA, 2007: Table 2).

Office	**Natural log of monthly hours of operation**	**Monthly hours of operation**	**Annual hours of operation**
Operating hours	3.972	53	2761

Table 75: Site energy to source energy conversion factors for electricity and gas in the USA. Source: (Ueno & Straube, 2010: 4)

	Site-to-source conversion factor
Electricity	3.365
Natural gas	1.092
HFO	1.158

Table 76: Percentage share of each fuel use in a typical office building in the USA. Source: (USA EIA, 2003: Table C1).

	Site electricity	**Natural gas**	**Fuel oil**	**District heat**	**Total**
Office - trillion btu	719	269	18	128	1134
Percentage share	63.40%	23.72%	1.59%	11.29%	

Table 77: Mean energy intensity data from USA EnergyStar (EPA, 2007: Table 2), converted to site energy to be comparable with Cape Town benchmarks. The proportion of fuels was based on CBECS data on office buildings (see Table 83). For source to site energy conversion factors see Table 82.

Office	**MJ/ft^2**	**MJ/m^2**	**kWh/m^2**
Source energy/square foot	198	2136	593
Site energy/square foot	106	1137	316

8.3 UK TM46 Benchmarks

Table 78: Office benchmark. Source: (Field, 2008: Table 1).

Office	**Electricity benchmark /kWh/m^2**	**Fossil-thermal benchmark /kWh/m^2**	**Median/ kWh/m^2**
General office	95	120	215

Table 79: Average energy intensities of all retail buildings from the UK TM46 Benchmarks. Source: (Field, 2008: Table 1).

Retail	**Electricity benchmark /kWh/m^2**	**Fossil-thermal benchmark /kWh/m^2**	**Median/ kWh/m^2**
High street agency	140	0	140
General retail	165	0	165
Large non food shop	70	170	240
Small food store	310	0	310
Large food store	400	105	505
Mean of above			**27**

8.4 Portion of energy used for heating and cooling

Table 80: Proportion of energy used for heating and cooling. Sources: (Action Energy, 2000: Table B1; USA EIA, 2003: Table E6A).

	UK offices	**USA retail**	**USA offices**	**USA other**
Proportion of energy used for heating	44%	8%	5%	2%
Proportion of energy used for cooling	7%	15%	14%	13%

Appendix 9: Useful conversion factors

Table 81: Fuel conversion factors used in calculations (source: SEA, 2003a: table 2.1)

	From	To
Electricity	1 kWh	0.0036 GJ
Coal	1 kg	0.031 GJ
HFO	1 litre	0.040 GJ
Diesel	1 litre	0.037 GJ
Paraffin	1 litre	0.036 GJ
Wood	1 bag (assume 10kg)	0.19 GJ
LPG	1 litre	0.000025 GJ

Table 82: Energy conversion factors (source: DoE RSA, 2009: 61)

From	**J (joule)**	**kWh (kilo Watt hour)**	**toe (ton oil equivalent)**	**Btu (British thermal units)**
1 J (joule)	1	0.278×10^{-6}	0.2388×10^{-6}	0.948×10^{-3}
1kWh	3.6×10^{6}	1	0.86×10^{-6}	3.412×10^{3}
1 toe	42×10^{9}	11630	1	39.68×10^{6}
1 Btu	1.055×10^{3}	0.293×10^{-3}	0.252×10^{-9}	1

Table 83: Prefixes

Prefix	**Symbol**	**Power**
Kilo	k	10^3
Mega	M	10^6
Giga	G	10^9
Tera	T	10^{12}
Peta	P	10^{15}