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Generating low-cost national energy benchmarks: A case study in commercial buildings in Cape Town, South Africa

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ABSTRACT

National benchmarks are a valuable tool for assessing and monitoring energy consumption in existing building stocks worldwide, but can be time consuming and expensive to generate. I explore a low-cost alternative by coordinating building related data collected by municipalities in South Africa for billing and rates purposes, to create energy use intensities (EUI) for the existing building stock. For a sample of commercial buildings in Cape Town, I link electricity data supplied by the municipality billing department with gross floor area data from the municipality valuation (rates) department, to establish EUIs. From these I calculate benchmarks that represent typical annual electricity usage for retail and office buildings in Cape Town. In addition I identify a number of improvements to data quality and access that would enable South Africa to realise the current opportunities that exist in the structure of its building data collection. In doing so South Africa can potentially leapfrog many other countries in the development of performance-based benchmarks and rating tools for a range of building activities, positioning it at the forefront of building energy-data collection.

1. Introduction

Energy consumed within existing buildings accounts for up to 40% of the annual world energy consumption [1]. Although the greatest savings in energy use per building can often be achieved in new buildings, the largest overall energy savings are often achieved by retrofitting existing buildings [2]. Improving the understanding of the energy consumed in existing buildings is therefore a high priority for those seeking to reduce energy consumption and hence carbon emissions in the national building stock [3].

A critical element for implementing any building energy-efficiency strategy in existing building stock, is measuring and monitoring energy use and setting and meeting targets for improvement. Benchmarks can provide a mechanism for this by defining a value that represents typical energy use, against which any building can be compared. Energy benchmarks are a key part of the process of generating energy ratings, an important tool for comparing and ranking the energy performance of buildings.

South Africa has set ambitious targets for improvements in energy-efficiency, aiming for a 15% improvement by 2015 [4]. Generating energy use benchmarks for existing buildings is an important part of realising this target. The most common approach to generating energy benchmarks for existing building stock involves collecting energy use data from a sample of individual buildings considered to be representative of the national building stock (e.g. [5,6]). This is often achieved by collecting data through surveys, such as the USA Commercial Buildings Energy Consumption Survey (CBECS) [8], which asks building managers for specific data on energy consumption and building characteristics. A study undertaken in Cape Town in 2008 used the survey approach on a small scale to generate good practice benchmarks from a sample of 20 commercial buildings [9]. Although this study produced useful data, it was too small a sample to be applicable to a national scale. In 2012 the Green Building Council of South Africa (GBCSA) commissioned a larger survey to develop a benchmark methodology for integrating into the South African Greenstar environmental certificate for existing office buildings [10]. This study included undertaking a basic survey of 155 office buildings and a detailed survey of 87 office buildings throughout South Africa and presents the development and details of performance based benchmarks for South African office buildings based on the survey results. However surveys collecting energy performance data on other building activities such as retail, hotels and schools have not been undertaken in South Africa. This is largely because such surveys are expensive and time consuming to undertake, factors that have limited the development of national benchmarks in many countries to date [11].

With survey data lacking, alternative energy rating systems have been developed for South African commercial buildings relying on alternative benchmarks. The EnerKey performance

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certificate [12] and the Energy Barometer [13] both generate energy ratings for a selection of different commercial building activities. The EnerKey performance certificates use the design targets for regulated energy usage for new buildings, developed for the South African national building regulations [14], as the comparison benchmark. This approach allows building operators to track their progress each year against the national design targets and allows buildings to be compared against each other between years. However, as the design targets were developed using computer simulated archetypes, many existing buildings vary significantly in operating hours and levels of comfort for the tenant operated items (such as lighting, small power, heating and cooling), from the standard operating profiles and values used to generate the design targets. This often results in operational energy consumption values being much greater than the design target values. The Energy Barometer energy labelling scheme, compares the building under consideration against benchmarks developed from buildings assessed using the scheme in the previous year. This approach allows participants to track their progress each year with regard to the industry average. However, it does not allow buildings to be compared against each other between years, and the buildings used to generate the benchmarks will not necessarily provide a representational sample of national building stock.

In this study I develop an alternative to the above techniques, which has the potential to access energy data for 60% of the electricity customers in South Africa. As electricity dominates energy consumption in commercial buildings in South Africa [15], it was considered that electricity benchmarks would provide a useful indicator of energy performance. This allows for the data collection process to be simplified considerably compared to countries where multiple fuels are used. The process can be further simplified in South Africa as around 60% of the electricity customer base is supplied by local municipalities [16]. This contrasts dramatically with other countries, which often have a proliferation of independent energy suppliers (e.g. the UK has over 70 suppliers of electricity and gas [17]). As municipalities also collect building related data for purposes such as rates calculations, this provides the opportunity to develop a comprehensive building stock database from data that is already collected. I explore this opportunity by linking electricity sales data obtained from the City of Cape Town municipality electricity billing department [18] with gross floor area data obtained from the City of Cape Town municipality on-line valuations database [19], to create energy use intensities (EUIs). Further these data are used to generate energy benchmarks for office and retail buildings in the City of Cape Town.

2. Methodology

Following methods typically used for generating energy benchmarks for existing buildings (e.g. [5–8]), I calculated energy use intensities (EUIs) for a sample of commercial buildings in Cape Town. In the context of this study the EUI is defined as annual energy consumption per square metre (kWh/m^2). I defined the annual energy as the whole building annual electricity consumption in kWh and the building area as the gross lettable floor area of the whole building in m^2. Although many rating schemes consider source energy (also described as final or primary energy) or carbon emissions, baseline benchmarks are usually presented in the form of site energy and converted to source energy or carbon emissions using national average conversion factors during the comparison process [20]. This allows for the conversion factors to change annually with differing national energy generation strategies without impacting the initial benchmark database. I collected site energy data from monthly electricity sales data collected for billing purposes by the Cape Town municipality [18]. Following the recommendations given by UNEP for a common carbon metric [21], I selected gross lettable area (m^2) of the building as the EUI indicator.

Monthly electricity billing data was provided for a sample of electricity consumers on the 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% of consumers on the municipality LPU tariffs. To convert the electricity billing data into useful EUIs I applied the following four filters to the dataset:

Building sector – The building sectors represented in the initial sample were commercial, agricultural, residential, public sector, industrial and unknown. I excluded all buildings not in the commercial sector. I defined the commercial sector as all non-residential buildings except public-sector buildings, industrial, agricultural, and unidentified buildings. After the building sector filter had been applied to the sample there were 422 commercial electricity customers remaining.

Building activity – Due to the diverse nature of activities undertaken in commercial buildings I grouped similar building activities to allow more specific benchmarks. I divided the customers into nine building activity categories (retail, catering, accommodation, office, warehouse, education, healthcare, mixed use, and other). Any buildings that could not be classified into these categories were discounted. I developed the categories from reviewing existing building performance databases [5], [8], and reviewing standard classification systems used internationally that define economic activity [22]. The final selection of building activities followed those used in the Greenhouse Gas Inventory for South Africa [23], with the addition of mixed use buildings as recommended by the United Nations Environment Programme (UNEP) [21]. I assigned building sector and activity using the customer names provided with the electricity billing data.

Energy use intensity (EUI) indicator – To obtain floor area data for each building in the electricity sample, I used the ERF number for each building to access the relevant information in the municipality's on-line valuation database. The ERF number is the existing national system intended to be a unique identifier for each building plot. Any building for which floor area could not be determined due to lack of necessary data was excluded from the sample. After the EUI indicator filter had been applied to the sample there were 158 commercial electricity customers remaining.

Analytical – To test whether the selected EUI indicator of floor area was legitimate for the Cape Town sample, I fitted a linear model to the data using least square regression. Examination of the residuals revealed that buildings with very low (less than 100 kWh/m^2) and very high (greater than 500 kWh/m^2) annual energy intensities, invalidated the assumptions of a linear model. In the case of retail the low energy intensities were generally associated with warehouse style retail premises. The high energy intensities, were associated with large retail businesses, where the extent of the premises included in the billing data was not clear, hence it was likely that floor area was underestimated. For the office sample the reason for the very high and very low energy intensities was less clear, but is also likely to be due to anomalies between the buildings that were included in the billing data and those included in the associated floor area calculations or due to low or unoccupied premises. Based on the linear relationship indicated by the statistical analysis, the floor area was considered to be a suitable EUI indicator only for buildings with EUI's greater than 100 kWh/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.