

BEHAVIOUR-BASED FACILITIES ENERGY MANAGEMENT FRAMEWORK FOR
HIGHER EDUCATION STUDENTS' RESIDENCE IN GHANA

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UNIVERSITI TEKNOLOGI MALAYSIA

BEHAVIOUR-BASED FACILITIES ENERGY MANAGEMENT FRAMEWORK
FOR HIGHER EDUCATION STUDENTS' RESIDENCE IN GHANA

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Facilities Management)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

JANUARY 2017

To my wife, Mrs. Naomi Adjei-Twum and our children: Emmanuel Adjei-Twum, Nana Akosua Difie Adjei-Twum, Adwoa Afriyie Adjei-Twum and Yaw Osei Adjei-Twum

ACKNOWLEDGEMENT

I wish to take this opportunity to express my gratitude to all whose contribution, directly or indirectly, have brought this thesis to this far.

Without the protection and guidance of the Almighty God nothing could have been achieved. I, therefore, sincerely thank God for taken me through my entire stay and study in Universiti Teknologi Malaysia.

To my supervisors, Assoc. Prof. Dr Maimunah Binti Sapri and Dr Sheau Ting Low, I owe my deeply heartfelt gratitude. They have proven to be professionals in the field of facilities management, as well as mothers to me during my stay and study in Malaysia; their invaluable guidance, comments and criticisms have seen me through my research.

Other categories of people who need not to be forgotten for their precious contribution to my study, are my study respondents and research assistants. I appreciate your time and opinions provided to make my study a reality.

I also want to extend my appreciation to my employers, Kumasi Polytechnic, who partly funded my study, without whose financial support and permission I would not have been able to pursue my PhD programme. Furthermore, I thank all my friends and my colleagues in Ghana and in Universiti Teknologi Malaysia who extended helping hands in diverse ways during my research work; I thank my church members, both in Ghana and Malaysia for their continual prayers and encouragement towards the achievement of my PhD dream.

Last, but not the least, I would want to express my deepest appreciation to my family, especially, my wife and children for their patience, sacrifice, support and encouragement in diverse ways which have enabled me to successfully complete this thesis.

ABSTRACT

Adopting desirable energy-related behaviours in built facilities have greater potential towards reducing the demand for energy and energy savings. Promoting desirable energy behaviour can be achieved through understanding of users' behaviour and its determinants to develop appropriate energy saving programmes. However, research on facilities users' behaviour and facilities energy management is limited within the domain of facilities management, especially in the higher education environment. The main question addressed in this study is: how can users' behaviour be incorporated into facilities energy management? This study aims to explore the energy use behaviour of students living in higher education residential facilities. The objectives were to determine the factors that influence residential students' energy use behaviour from the students' and managers' perspectives respectively; to identify energy management practices implemented in the residential facilities; and to develop a behaviour-based facilities energy management framework. To achieve these objectives, the study adopted a multi models approach to mixed methods research. The study was situated within pragmatist paradigm with emphasis on qualitative approach. Implementation of energy management practices and energy use behaviour of students from six higher education institutions in Ghana were investigated using survey, semi-structured interview and focus group. Descriptive statistics were used to analyse the survey data whilst interview and focus group data were analysed using content analysis with MAXQDA 12 qualitative analysis software. Analysis of both the survey and the interview data revealed that, energy management practices were least implemented in all the institutions. In addition, the results indicate that there is much room for improvement in students' energy saving behaviour. Furthermore, the analysis revealed four key factors that influence students' energy use behaviour from the managers' perspective: institutional, economic, perceived behavioural control and attitude. From the students' perspective, five key factors were found to influence students' energy use behaviour across all the four behaviours studied: attitude, social, habit, physical and economic factors. The study developed and validated behaviour-based facilities energy management framework (BFEM) to manage energy in students' residential facilities. This study contributes to knowledge by integrating individuals' behaviour, energy management and facilities management toward energy savings.

ABSTRAK

Amalan tingkah laku yang baik terhadap penggunaan tenaga bagi sesebuah fasiliti yang disediakan mempunyai potensi yang besar dalam penggunaan dan penjimatan tenaga. Dorongan terhadap tingkah laku yang baik boleh dicapai melalui pemahaman tingkah laku pengguna dan faktor–faktor penentunya bagi membangunkan program penjimatan tenaga yang sesuai. Walau bagaimanapun, penyelidikan dalam bidang pengurusan tenaga fasiliti dan tingkah laku penggunaan fasiliti adalah terhad, terutamanya dalam peringkat pengajian tinggi. Persoalan utama kajian ini ialah: bagaimana tingkah laku pengguna boleh digabungkan dalam pengurusan tenaga fasiliti? Matlamat kajian ini adalah untuk mengkaji secara terperinci tingkah laku penggunaan tenaga oleh pelajar yang tinggal di kolej kediaman institusi pengajian tinggi. Objektif kajian ini adalah untuk menentukan faktor yang mempengaruhi tingkah laku penggunaan tenaga pelajar di kolej kediaman dari perspektif pelajar dan pengurus; untuk mengenalpasti amalan pengurusan tenaga bagi fasiliti di kolej kediaman pelajar; dan untuk membangunkan membangunkan rangka kerja pengurusan tenaga fasiliti yang berasaskan tingkahlaku. Untuk mencapai objektif ini, kajian telah menggunakan pendekatan pelbagai model dalam kaedah kajian campuran. Kajian ini terletak di dalam paradigma pragmatis dengan memberi penekanan kepada pendekatan kualitatif. Perlaksanaan amalan pengurusan tenaga dan tingkah laku pelajar terhadap penggunaan tenaga di enam kolej kediaman institusi pengajian tinggi di Ghana telah dikaji menerusi kaji selidik, temu bual semi struktur dan kumpulan fokus. Statistik deskriptif telah digunakan untuk menganalisis data kaji selidik manakala temu bual dan data kumpulan fokus telah dianalisis menggunakan analisis kandungan melalui MAXQDA 12 yang merupakan satu perisian analisis kualitatif. Analisis kaji selidik dan data temubual telah menunjukkan bahawa amalan pengurusan tenaga kurang dilaksanakan di semua institusi. Dapatan kajian menunjukkan bahawa terdapat banyak ruang untuk meningkatkan tingkah laku pelajar dalam penjimatan tenaga. Selain itu, analisis dari perspektif pengurus mendapati empat faktor utama yang mempengaruhi tingkah laku pelajar terhadap penggunaan tenaga: institusi, ekonomi, tanggapan kawalan gelagat dan tingkahlaku. Dari perspektif pelajar, terdapat lima faktor yang ditemui dapat mempengaruhi tingkah laku pelajar terhadap tenaga: faktor sikap, sosial, tabiat, fizikal dan ekonomi. Kajian ini membangunkan dan mengesahkan rangka kerja tingkah laku berasaskan pengurusan kemudahan tenaga (BFEM) untuk menguruskan tenaga di kemudahan kediaman pelajar. Kajian ini menyumbang kepada ilmu pengetahuan dengan menggabungkan tingkah laku individu, pengurusan tenaga dan pengurusan fasiliti ke arah penjimatan tenaga.

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LIST OF ABBREVIATIONS

BCP	-	Behaviour change programmes
BFEM	-	Behaviour-based facilities energy management framework
BMS	-	Building management systems
CMB	-	Code matrix browser
CRB	-	Code relations browser
EMP	-	Energy management practices
EUB	-	Energy use behaviour
FEM	-	Facilities energy pyramid
FM	-	Facilities management
FMAA		Facilities Management Association of Australia
FEMP	-	Facilities energy management programme
GHG	-	Greenhouse gases
HEI	-	Higher education institution
HESRF	-	Higher education students' residential facilities
IFMA	-	International Facilities Management Association
ISO	-	International Organisation for Standardization
M&E	-	Monitoring and evaluation
OAP	-	Overall average of percentages
OECD	-	Organisation for Economic Co-operation and Development
PBC	-	Perceived behavioural control
P-PM	-	PRECEDE-PROCEED model

SG	-	Summary grid
ST	-	Summary table
TIB	-	Theory of interpersonal behaviour
TPB	-	Theory of planned behaviour
TRA	-	Theory of reasoned action

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The usefulness of energy to humanity cannot be overstated. Energy is required in almost every aspect of human life, e.g., in commercial activities and educational activities. Energy is described as the “golden thread” that bonds economic growth, social equity, and environmental sustainability (Frei , 2013; Ki-moon, 2012). Thus, the inadequacy or lack of energy would tremendously hamper the growth and development of business organisations, nations and the world economy at large (Sovacool *et al.*, 2014; Birol, 2007).

However, the world is beset with a number of energy-related challenges. These challenges include increasing energy demand (energy security), environmental consequences of energy generation and consumption, energy poverty and energy price volatility all of which are threat to energy sustainability (Low *et al.*, 2012). Energy security involves having access to continuous supply of adequate energy at affordable price (Hoeven, 2013; Asif and Muneer, 2007; OECD/IEA, 2007). The critical role energy plays in human development and economic growth makes energy security a great concern. However, energy is a resource with a limited life span for which excessive consumption would lead to its rapid depletion (Keefe and Grimshaw, 1994). With the world economy structured around oil and other fossil fuels (Sovacool *et al.*, 2014), and increasing demand for energy (Sovacool *et al.*, 2014; Omer, 2008) which

is associated with economic growth, energy security would continue to be a significant issue.

Also, another energy issue is price volatility which is influenced by oil price because oil is a major source of energy. Energy price appears to be more volatile than other commodities (Ebrahim *et al.*, 2013; Cantore *et al.*, 2012; Regnier, 2007; Plourde and Watkins, 1998). The uncertain nature of energy prices is of great concern to many people (World Energy Council, 2015); has both direct and indirect consequences (Ebrahim *et al.*, 2013; Ven and Fouquet, 2014). Directly, oil price fluctuation affects consumption, investment and production; increasing oil price results in increase expenditure on energy which leads to rise in the prices of goods and services whereas indirect consequences include effects on inflation and unemployment (Ebrahim *et al.*, 2013).

Furthermore, energy poverty is another critical energy challenge which is socially-related and refers to lack of access to modern energy services (Biol, 2007). It is estimated that about 1.3 billion people (18.6%) in the world are without access to electricity (Biol, 2012; World Energy Council, 2013). Access to modern energy services and electricity has been linked to development and reduction of poverty (Sovacool *et al.*, 2014; Biol, 2007). Lack of access to modern energy hampers skills development; prevents people from taking part in the global economy whilst providing access to energy creates a platform for people's development (Sovacool *et al.*, 2014; Biol, 2007). Biol (2007) suggests that commitment, political will and investments in energy infrastructure by world leaders and governments are needed to address energy poverty.

Moreover, majority of the sources of energy supply in the world, such as oil, coal, and natural gas are carbon laden, which have high environmental consequences (Lior, 2008; Holdren and Smith, 2000). Therefore, the more energy we consume, the more carbon we are likely to emit into the atmosphere. Previous studies have shown that energy consumption in buildings is associated with emission of high proportion of carbon dioxide and other greenhouse gases (GHG). For example, it has been

highlighted that buildings are responsible for 25-40% GHG emissions in Organisation for Economic Co-operation and Development (OECD) countries (Wilde and Coley, 2012); 38% of the total GHG emissions in 2009 in UK (Coleman *et al.*, 2013); and account for 48% GHG emissions in the USA (Janda, 2011). These emissions are sources of severe weather conditions, depletion of the ozone layer and other environmental degradations (Holdren and Smith, 2000).

Against this backdrop, it becomes utmost important to prioritize the energy issues on the agenda of the international bodies, nations, business organisations as well as individuals as remarked by Ki-moon (2012) that “we can no longer burn our way to prosperity”. Lior (2008) suggests that it is important and possible to reduce energy consumption. This is consistent with the call to using energy efficiently which is vital (Hoeven, 2013; Wiggins, 2010) and appears to be the way to go. Using energy efficiently means small amount of energy is used to accomplish the same task without affecting the quality of life of facilities users or an organisation’s business (c.f. Patterson, 1996). Efficient use of energy entails changing one’s habit and behaviour that are energy wasting to adopt energy saving ones (Hoeven, 2013). Examples of efficient ways of using energy include turning off lights when spaces are unoccupied, making optimum use of daylight and practising bulk ironing. In other words, mitigating energy challenges would require judicious use of energy as a way forward, which is the subject of energy management (Capehart *et al.*, 2008).

This need for prudent use of energy calls for effective management of energy which would be achieved through facilities management (FM). One of the objectives of FM is to improve the efficiency of the built environment (Cotts *et al.*, 2010) and FM’s role in energy management has been acknowledged. Several studies have been carried out in FM that identify energy management as one of the key functions of FM (e.g. Chotipanich, 2004). In addition, FM has been the forerunner towards achievement of sustainability agenda through sustainable FM (Elmualim *et al.*, 2012) of which energy issues are major component (Alexander, 1996).

1.2 Brief Description of Ghana

This section presents a brief background of Ghana. Ghana is a West African country located at the shores of Gulf of Guinea and the Atlantic Ocean, within latitudes 4.5° and 11.5° north of the Equator and between Longitudes 3.5° west and 1.3° east; and shares borders with La Cote D'ivoire to the west, Republic of Togo to the east and Burkina Faso to the North. Ghana's population is estimated at 28 million (www.worldpopulationreview.com) with a gross domestic product of US\$48,678 million, which is made up of service sector (49.5%), industry sector (28.6%) and agricultural sector (22.0%). The section discusses the climate and energy situation Ghana.

1.2.1 Climatic Situation in Ghana

According to the Köppen climate classification system, Ghana falls within the tropical climate with clear sky and high temperatures (Marihellum, 2013; Kottek *et al.*, 2006). Ghana experiences two main types of climatic conditions which are influenced by two types of air masses that blow over the country: North-eastern dry and hot wind blowing from the Sahara Desert and south western moist wind from the Atlantic Ocean. These air masses create dry season (harmattan) and rainy season respectively. However, Ghana is divided into three major climatic zones: northern savannah with dry season of hot days, cool nights and clear skies as its key features; tropical forest with two rainy seasons from April to July and September to November; and coastal savannah with similar characteristics as the northern savannah zone (see Figure 1.1). Average annual temperature is quite similar across the country, ranging between 26°C and 29°C ; however, daily variation is greater in the northern zone than it is in the coastal zone (www.ghana.climateps.com).

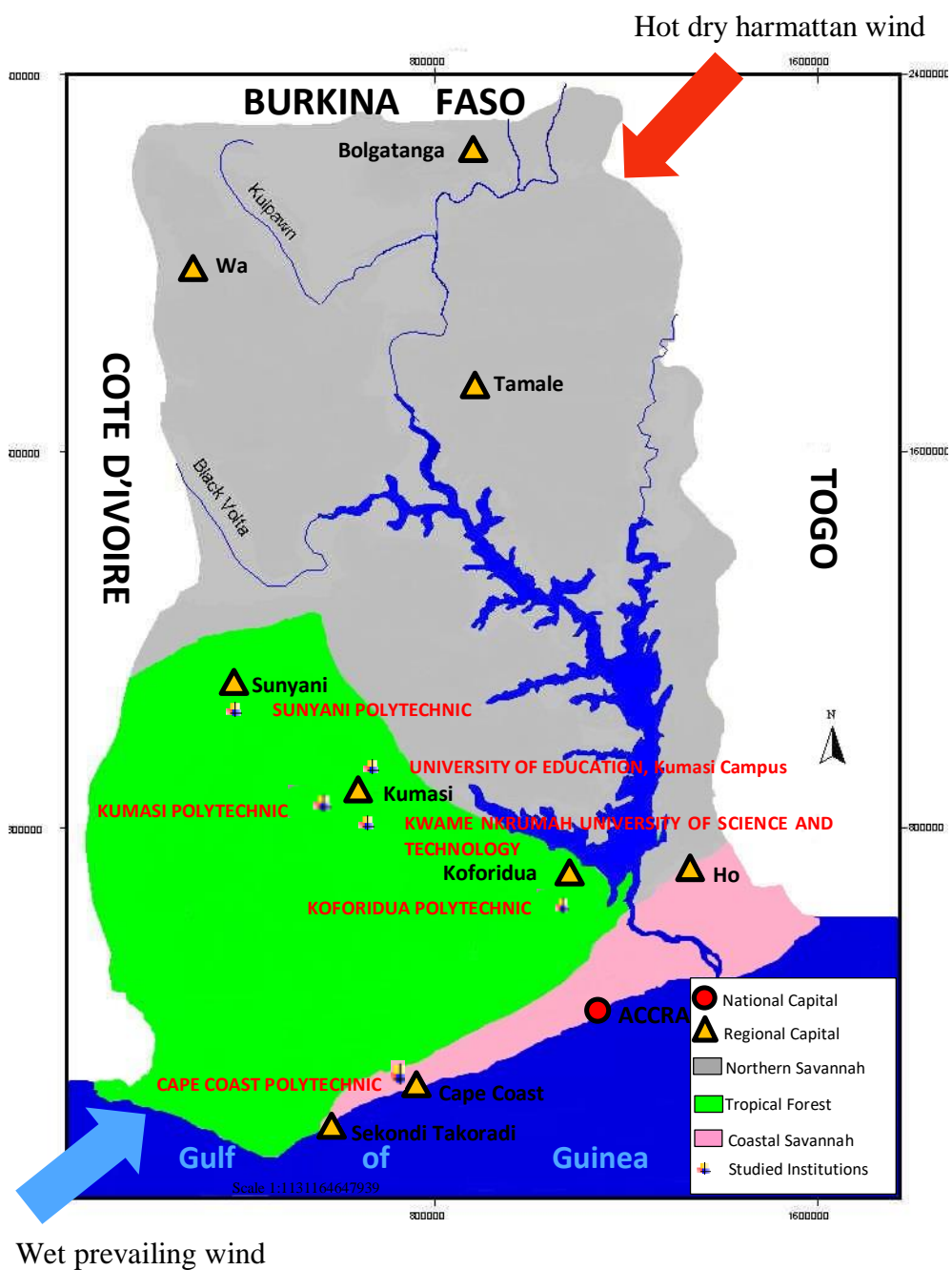
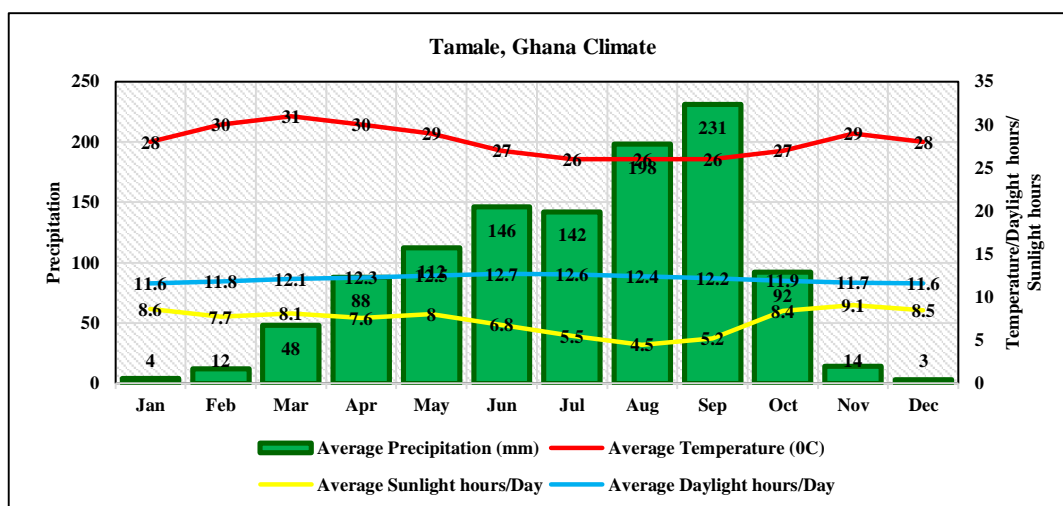
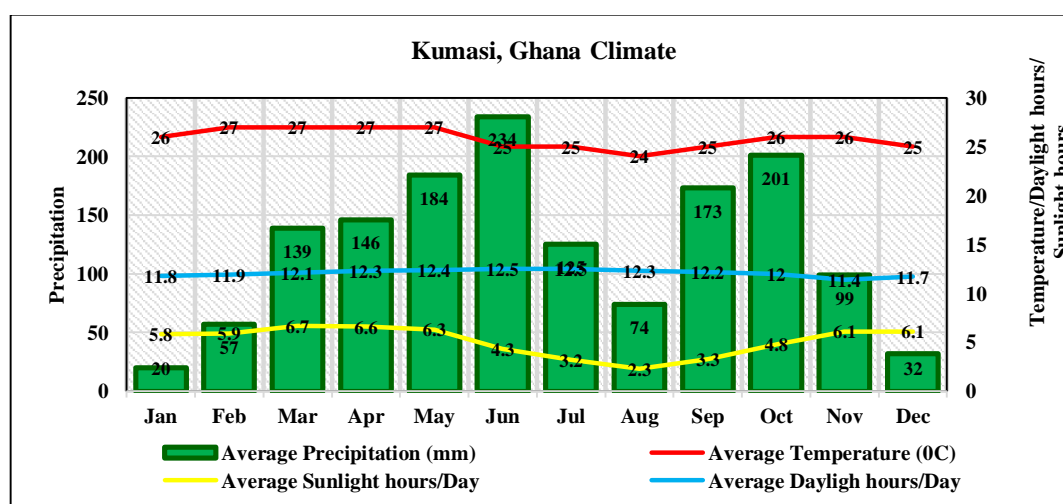


Figure 1.1: Map of Ghana showing Climatic zone (Marihellum, 2013)

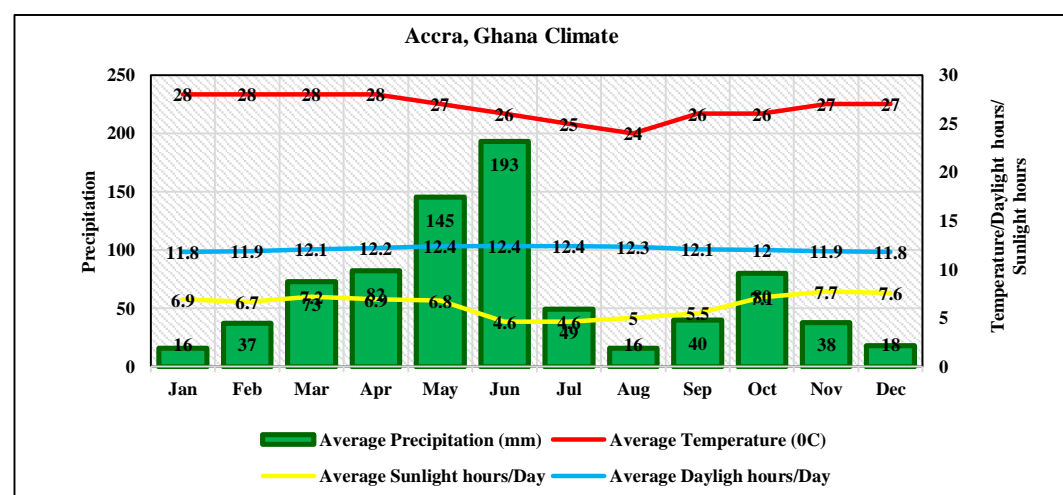
Moreover, in terms of sunlight and cloudy conditions which reflects the clearness of the sky, Figure 1.2 A-C present the average sunlight hours per day and the length of daylight hours per day of the three climatic zones, represented by the cities: Tamale (Northern savannah), Kumasi (Tropical forest) and Accra (Coastal savannah). As can be seen from these figures, Ghana has average daily daylight hours ranging between 11.4 and 12.7 hours, fairly stable throughout the year across the three zones



(A)



(B)



(C)

Figure 1.2: Climate of Three cities that represent the three climatic zones of Ghana
(www.ghana.climatemps.com)

whilst average daily sunlight hours ranges between 2.3 and 9.1 hours, with the lower hours occurring between July and September. However, these durations of sunlight per day varies across the climate zones, with tropical forest recording lower daily sunlight hours throughout the year. The months of October to March have sunny skies. With clear skies, as depicted by the length of daylight hours and sunlight hours, the use of natural light within built facilities appears possible with appropriate designs of these facilities; and other factors which affect energy saving behaviours, which the study seeks to explore within HESRF.

In relation to natural light usage in the built facility is daylight factor, which refers to the ratio of indoor light levels to outdoor light levels expressed in percentages (Koranteng *et al.*, 2012). This daylight factor is typically influenced by the building design. According to Hopkins *et al.* (1996), minimum daylight factor of 0.5%, 1% and 4% are respectively appropriate for a bedroom, living room and rooms used for computing and typing, with which the use of natural light is made possible. However, most of the designs of the HESRF studied appears to clearly make the use of natural light possible (see Appendices O1, O2, P1 and P2 for photographs and floor plans of typical HESRF). These plans also show the distribution of light switches in the various rooms and balconies with some rooms having separate switches for different lights while others have only one switch for the number of lights provided in the rooms.

1.2.2 Energy Situation in Ghana

There are three main types of energy sources in Ghana: Biomass (64%), petroleum fuels (27%) and electricity (9%) (Gyamfi *et al.*, 2015). Although electricity accounts for 9% of the total energy mix, it is the main type of energy used in buildings which accounts for about 36% in residential sector and about 65% in service (e.g. offices, educational institutions) and manufacturing industries (Eshun and Amoako-Tuffour, 2016). Electricity is produced from two main sources – hydro and thermal, supplemented by imports and/or solar (Energy Commission of Ghana, 2011, 2013, 2015a). The thermal plants mostly use natural gas or crude oil as their raw materials

for electricity production. Over the years, the composition of electricity generation sources has been shifting from hydro to thermal and then recently, inclusion of solar (see Table 1.1). The implication of this move towards thermal is that more fossil fuels (e.g. oil) would be burned leading to increasing emission of GHG.

Table 1.1: Composition of electricity generation sources in percentages

Generation Sources	2000	2005	2010	2014
Hydro	91.50	87.93	68.81	64.70
Thermal	8.50	17.07	31.19	35.27
Solar	-	-	-	0.03

Sources: Energy Commission of Ghana (2011, 2013, 2015b)

Until the 1970s world energy crisis, Ghana never experienced any energy difficulties; electricity was in abundant supply and people were encouraged to freely use electricity, and high energy consumption was promoted through the use of boilers, kilns and furnaces in the industry (Ofosu-Ahenkorah, 2007). Since then Ghana began to learn about the need to conserve energy; and has gone through a series of power crises from then till date (Brew-Hammond and Kemausuor, 2007).

Ghana is confronted with many energy-related challenges which make energy management extremely important. These challenges include energy insecurity, energy poverty, environmental and economic challenges. The key among these challenges is energy security as explained above which refer to continuous supply of energy at affordable price; hence the situation where there is inconsistent, unreliable supply of energy (electricity) and which are not affordable could be termed energy insecurity.

Demand for electricity in Ghana has been increasing due to expansion of the economy and population growth. Table 1.2 shows the energy consumption pattern in Ghana by sector from 2005 to 2014. As it can be seen, total electricity consumption increased from 5,259 KWh in 2005 to 10,182 KWh in 2014, a total increase of 93.6%, over 10-year period with all sectors more than doubling their values at 2005. This

gives approximately 10% annual increase in demand for electricity. The highest increase in the consumption occurred in the provision of street lights (349.4%), though this consumption formed only 4% of the total consumption in 2014. This was followed by about 164.8% for residential sector, and 125% and 106.7% for non-residential and industrial sectors respectively. Such an increase appears to persist as the country continues to pursue upward economic development.

Table 1.2: Electricity consumption (GWh) in Ghana by sector (2005-2014)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Residential	1,956	2,130	2,095	2,269	2,418	2,738	2,761	2,803	3,228	3,223
Non-Residential	676	790	802	927	884	966	1,041	1,153	1,525	1,522
Industrial	2,542	3,593	2,687	2,963	2,921	3,156	3,900	4,153	4,224	5,055
Street Lighting	85	144	137	171	184	264	274	315	377	382
Total	5,259	6,657	5,721	6,330	6,407	7,124	7,976	8,424	9,354	10,182

Source: Energy Commission of Ghana (2015b)

In addition, whilst demand for electricity continues to rise, supply has consistently lagged behind (Table 1.3). As can be seen, actual electricity supplied since 2010 has always fallen below required demand. This situation has resulted in load shedding since 2012. Other means of addressing the shortfall entail importing power from neighbouring countries such as La Côte d'Ivoire (Ministry of Energy, 2010), an approach the Energy Commission of Ghana (2006) describes as risky and could threaten the countries energy security.

Table 1.3: Electricity demand and supply (GWh) in Ghana from 2010-2014

Year	Required amount of electricity (Demand)	Actual supply	Energy Mark-up
2010	13,848-17,484	10,232	3,616
2011	13,300-14,488	11,200	2,100
2012	12,394-14,673	12,164	230
2013	13,667-15,794	12,927	740
2014	14,571-15,351	12,906	1,665

Source: Energy Commission of Ghana (2011-2015a)

Furthermore, increasing energy demand requires more investments to be made in the provision of energy infrastructure, to expand generation plants which are capital intensive. However, inability to produce adequate electricity has drastically affected Ghana's economic growth. For example, the energy crisis over the period has resulted in downward growth in the country's gross domestic product (GDP): consistently reducing from 14.4% in 2011 to 8.8% (2012), 7.1% (2013), 4.2% (2014) and projected to fall to 3.5% in 2015; losses due to energy crisis in 2007 and 2014 amounted to about 1.8% and 2% of GDP respectively (Energy Commission of Ghana, 2015a).

In addition, inadequate supply of electricity is associated with increasing unemployment. The energy crisis coupled with high tariffs has made some companies to fold up while others lay off employees because of high operational cost resulting in high unemployment in Ghana (Opare, 2016). Furthermore, one key reason that is regularly assigned to the shift from hydro power generation to thermal is changing and unreliable rainfall pattern as a result of which the country's three hydropower plants are not able to operate at their full capacity (Gyamfi *et al.*, 2015).

Moreover, in Ghana all government institutions, including public higher education institutions (HEI) were not paying for the electricity they use; utilities had always been the responsibility of government and for that matter, students of higher education are not levied for electricity use (Sapri *et al.*, 2016, Ofosu-Ahenkorah, 2007). This is a clear disincentive to adopting energy saving behaviour in the non-residential sector where facility users have no personal or financial interest (Carrico and Riemer, 2011). This disincentive is expressed by the Energy Commission of Ghana as:

If someone else pays your electricity bills like it happens in government institutions, you don't care because you may not even see the bill, as the Minister of Finance collects the bills and pay on your behalf.
(Ofosu-Ahenkorah, 2007)

With lack of financial obligation, organisations would not think of putting in place measures and programmes to manage and reduce energy consumption. Energy waste

by end-users are clearly visible throughout the country which is noted in Ghana's strategic national energy plan as a challenge of inefficiency in the end-use of energy resulting in wasting of energy (Energy Commission of Ghana, 2006). In addition, inefficient use and management of utilities, is the basis for government directive to public institutions to pay for their electricity consumption (Ministry of Finance, 2014). By this directive, higher education students would eventually be made to pay for the electricity they use, especially, those in residence. Recognising the high amount of energy consumed by students, the government targeted higher education students' residential facilities (HESRF) for initial introduction of prepayment meters; residential facilities were also targeted together for 50% reduction of their electricity consumption by 2015.

To reduce the burden on the power generation plants, end-users should use energy efficiently. Whereas regulations abound at national level to govern generation, distribution and transmission of electricity, none appears to exist that seeks to ensure that energy is properly used or managed, especially in organisations. The Energy Commission of Ghana in 2006 proposed for the enactment of Energy Efficiency and Conservation Act to deal with energy management practices (EMP) among other measures to ensure reduced energy consumption (Energy Commission of Ghana, 2006) which is yet to be enacted. As suggested by Turner *et al.* (2007), energy management is one of the surest means by which organisations and governments could meet energy challenges that confront them.

1.3 Problem Statement

Humanity's excessive energy consumption has great consequences on continuous supply of energy resources leading to rising energy prices, environmental degradation through carbon emissions, social development and economic growth of nations and organisations (Asif and Muneer, 2007; Holdren and Smith, 2000). One of the key contributors to this situation is energy used in built facilities (Coleman *et al.*, 2013; Janda, 2011; Burnett, 2007). These facilities consume large amount of energy

and emit huge amount of GHG, most of which are attributed to the behaviour of the users (Wilde and Coley, 2012; Gill *et al.*, 2010). Facilities users contribute significantly to excessive energy consumption in the built facilities through their behaviour. For example, Prodromou *et al.* (2009) suggest that behavioural patterns and improper use of buildings and its systems could result in excess energy consumption of 45% above the initially predicted levels. Unless energy is used efficiently and consumption reduced, individuals, organisations and nations would continue to be threatened with potential energy-related environmental, social and economic problems. Energy management appears to be one of the effective and surest ways to use energy efficiently and effectively (Turner *et al.*, 2007).

Previous researches on energy management in the context of FM focus on technological/technical approach to managing energy in organisations (Määttänen *et al.*, 2014; Escrivá-Escrivá *et al.*, 2010) to address the issues of energy wasting and higher energy consumption. Other studies also concentrate on developing tools to assist facilities managers in benchmarking energy consumption (Haji-Sapar and Eang Lee, 2005); assessing energy consumption (Junghans, 2013a); and in carrying out energy-led refurbishment of buildings (Strachan and Banfill, 2012). Yet, other studies focus on the role of FM personnel and their challenges in managing organisation's energy (Goulden and Spence, 2015; Aune *et al.*, 2009).

Certainly, technical/technological approach to energy management in organisations' facilities can lead to improved energy efficiency and energy consumption reduction, (Määttänen *et al.*, 2014; Yen *et al.*, 2010; Aune *et al.*, 2009). It is argued that adopting this approach alone would not suffice in addressing excessive energy consumption issues (Janda, 2009). Indeed, it is said that facilities users immensely contribute to facilities energy consumption through their behaviour and that technical approach alone is not sufficient to address energy efficiency problems (Janda, 2011; Gill *et al.*, 2010; Marans & Edelstien, 2010); users are great untapped potential to improve facilities energy performance and operations (Lopes *et al.*, 2012; Center for the Built Environment, 2010; Mashburn, 2007).

To the best of the knowledge of the researcher, least research attention has been given to behavioural aspect of energy management within FM, that is, studies that focus on facilities users' energy use behaviour (EUB) in facilities energy management appears to be lacking. During periods of escalating energy prices and imposition of taxes to ensure reduced carbon emissions, the need for influencing and reducing energy consumption in organisations becomes imperative, especially, for HEIs with dwindling budget, so as to eliminate energy wasting with its financial consequences on organisations.

In addition, less attention has been paid to research on HESRF in terms of energy management. Generally, HEIs possess huge and complex facilities that accommodate greater number of people, used for wider variety of purposes (Sapri and Mohammed, 2010), and thus consuming high amount of energy (Petersen *et al.*, 2007). Residential students constitute important part of higher education community who consume substantial amount of energy; responsible for significant carbon emission (Petersen *et al.*, 2007) and are also significant sources of energy wasting (Galis and Gyberg, 2011). Understanding users' EUB and underlying determinants is significant for effective facilities energy management (c.f. Karlin *et al.*, 2014; Stephenson *et al.*, 2010).

Existing studies on residential students' EUB mostly use quantitative approaches with a focus on students as subjects of study (e.g. Hafizal *et al.*, 2015). However, an exploratory research, focusing on the phenomenon of students' EUB and its determinants from the perspectives of managers of HESRF and institutions facilities as well as students, would in addition to providing detailed views of study participants in their own words (Curry *et al.*, 2009), provide a holistic picture of the behaviour of students regarding energy use in their residence and related factors.

Exploring students' EUB from two perspectives alongside energy management implementation, would enhance our understanding of how students use energy in their facilities and the factors that influence them. It would assist in developing appropriate energy management framework with users' behaviour as the main focus; enable

facilities managers to incorporate students' behavioural determinants into their energy management programmes by involving students in decisions and activities concerning energy.

1.4 Research Questions

The main question addressed in this study is: how can students' behaviour be incorporated into energy management in students' residential facilities? The specific research questions to be addressed are as follows:

1. What are students' perspectives of residential students' energy use behaviour?
2. What are managers' perspectives of residential students' energy use behaviour?
3. What energy management practices are implemented in higher education students' residential facilities?
4. How can students' behaviour be incorporated into energy management in higher education students' residential facilities?

1.5 Research Aims and Research Objectives

The aim of this study is to explore energy use behaviour of students of HEIs to be incorporated into energy management in students' residential facilities. The study addresses the following specific objectives:

1. To determine the factors that influence energy use behaviour of residential students in higher education students' residential facilities from student's perspective.
2. To determine the factors that influence energy use behaviour of residential students in higher education students' residential facilities from manager's perspective.

3. To identify energy management practices in higher education students' residential facilities.
4. To develop Behaviour-based Facilities Energy Management framework (BFEM) for managing energy in higher education students' residential facilities.

1.6 Scope of Research

The study focuses on behaviour of students in relation to energy use, that is, electricity use, and measurement of EMP in residential facilities of HEIs. As a result, the research involves students living in HESRF from selected universities and polytechnics in Ghana. These institutions are College of Technology (University of Education, Winneba), Kumasi; Kwame Nkrumah University of Science and Technology; Kumasi Polytechnic; Cape Coast Polytechnic; Koforidua Polytechnic and Sunyani Polytechnic. Also, the study involved managers of the facilities and/or HESRF of these institutions. The research was limited to the exploration of students' EUB and determinants from two perspectives: student's perspective focusing on bulk ironing, lighting use (turning off light not in use and natural light use), and natural ventilation use; managers' perspective focuses on students' general energy EUB.

1.7 Outline of Research Methods

The section presents a brief overview of the process followed in carrying out this research as presented in Table 1.4. Details are provided in chapter 4.

Table 1.4: Research methodology outline

Objective	Activity	Output
Review of relevant FM and energy management concepts; behaviour/ behavioural change theories and models .	Review of literature	EMP, factors that influence energy behaviour and strategies to cause behaviour change identified
To conduct experts and students survey and analyse	Initial study	Specific energy saving behaviours identified for focus group sessions.
Objective 1: to explore students' EUB and influencing factors from students' perspective	Main study – Students-Data collection and analysis	Students' EUB explored and influencing factors identified from students' perspective.
Objective 2: to explore students' EUB and influencing factors from managers' perspective	Main study – Managers- Data collection and analysis	Students' EUB explored and influencing factors identified from managers' perspective.
Objective 3: to identify EMP implemented in the HESRF.		EMP implemented in the HESRF are identified.
Objective 4: To develop behaviour-based facilities energy management framework	Development and validation of framework	Behaviour-based facilities energy management framework
Report the results, findings as well as conclusion	Results, findings and conclusion	Study findings are reported and all study objectives are achieved

1.8 Organisation of the Thesis

The thesis is organised into nine chapters which are outlined below:

- Chapter 1:** This chapter provides overview of the complete research covering the background, problem statement, research questions, objectives, scope of study, and brief overview of methodology.
- Chapter 2:** The chapter reviews and summarises relevant literature relating to FM and energy management covering topics such as energy management practices (EMP), descriptive relationship of users and energy, place, technology and process in an organisation.
- Chapter 3:** The chapter reviews two behavioural theories and summarises key determinants of EUB, and one intervention planning model. The chapter deals with topics such as EUB, factors that influence EUBs and strategies for changing behaviour.
- Chapter 4:** The chapter outlines and explain the methodology employed in the study. It explains various parts of the study including philosophy, research approach, design, data collection and data analysis procedures.
- Chapter 5:** The chapter presents analysis and exploration of students' EUBs and their determinants from the perspective of students.
- Chapter 6:** In this chapter, students' EUBs and determinants are explored and analysed from the perspective of managers of students' residential facilities and/or institutions facilities.
- Chapter 7:** This chapter analyses and discusses EMP implemented in the HESRF.
- Chapter 8:** In chapter 8, the findings from chapters 5, 6 and 7 are integrated for the development of BFEM. The various components and validation of the framework are also discussed.
- Chapter 9:** This chapter concludes the study by providing discussion of findings in relation to previous studies, summarising the key study findings, contributions and limitations of the study and suggestions for further studies.

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