The development of an online energy auditing software application with remote SQL-database support

by

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DECLARATION

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ABSTRACT

In the last century the earth has experienced an increase in the global mean temperature, with the main contributing factor being the increase in greenhouse gasses. Evidence indicates that the burning of fossil fuels, critical in the supply of energy, contributed towards three quarters of the carbon dioxide (CO_2) increase. In 2008 South Africa reached electricity capacity constraints. A subsequent economic downturn experienced in the country, brought about by the worldwide economic recession, has relieved some of the strain on the electricity supply system. However, consumption levels are returning to those experienced during 2008 and no new base load power stations have been added. Short-term capacity constraints can be managed by shifting the peak demand, but the electricity shortage can only be avoided by adding additional capacity or reducing the overall electricity consumption. Supply-side solutions are both overdue and too expensive. The only solutions that can provide lasting results are demand-side solutions.

During the past few years the Energy Efficiency and Demand-side Management (EEDSM) programme implemented by South Africa's electricity supply utility, Eskom, has gained prominence. This programme relies heavily on calculating the savings incurred through any demand-side intervention. Energy audits enable the calculation of various consumption scenarios and can provide valuable insight into load operation and user behaviour. Energy audits involve a two-part procedure consisting of load surveying and an analysis. This thesis describes the development of both these procedures, combined into a single application. The application has been tested and provides an accurate and effective tool for simulating consumption and quantifying savings for various load adjustments.

The results gained from the auditing application surpassed the expectations and provides the user with a sufficient base-line consumption estimate. The results do not reflect day-to-day

variations, but the simulations are sufficient to quantify savings and determine whether demand-side interventions are financially viable. The application also presents a benchmark for the type of applications required to successfully implement an EEDSM programme.

OPSOMMING

In die afgelope eeu het die aarde se gemiddelde temperatuur toegeneem, met die toename in kweekhuisgasse as die grootste bydraende faktor. Dit wil ook voorkom asof die verbranding van fossielbrandstowwe, wat noodsaaklik is vir die verskaffing van energie, verantwoordelik is vir driekwart van die toename in koolstofdioksied (CO_2). Gedurende 2008 het Suid-Afrika elektrisiteitsbeperkings bereik. Die daaropvolgende ekonomiese afswaai wat in die land ervaar is weensdie wêreldwye ekonomiese resessie, het van die druk op die elekriese netwerk verlig. Verbruikersvlakke is egter besig om terug te keer na waar dit in 2008 was, maar geen nuwe basislas-kragstasies is gebou nie. Op die kort termyn kan die kapasiteitsbeperkings bestuur word deur die aanvraag te verskuif, maar die elektrisiteitstekort kan op die lang duur slegs vermy word deur bykomende kapasiteit by te voeg of die totale aanvraag te verminder. Toevoerkant-oplossings is beide agterstallig en te duur. Die enigste oplossings wat blywende resultate kan lewer, is dus aan die verbruikerkant.

In die afgelope paar jaar het die effektiewe bestuur van energieverbruik baie aansien geniet. Die nasionale energievoorsiener, Eskom, het ook 'n program geloods om te help met die implimentering van energiebesparingmaatreëls. Die implementering van energie-oudits om met die kwantifisering van besparings te help, is van integrale belang vir die sukses van die program. Energie-oudits stel die eindverbruiker in staat om verskeie verbruiksmoontlikhede te beproef en sodoende waardevolle inligitng te verkry rakende die verbruikspatrone van die fasiliteit. Energie-oudits behels 'n tweeledige proses, bestaande uit 'n lasopname en 'n verbruiksanalise. Hierdie proefskrif beskryf die ontwikkeling van 'n stelsel wat beide die prosesse kombineer in 'n enkele applikasie. Die applikasie is getoets en bied 'n akkurate en doeltreffende instrument om verbruik te simuleer en besparings te kwantifiseer vir verskeie verbruiksmoontlikhede.

Die resultate van die oudit het die aanvanklike verwagtinge oortref en voorsien verbruikers van 'n goeie skatting van die basisverbruik van 'n fasiliteit. Die resultate weerspieël nie dag-tot-dag variasies nie, maar die simulasies is voldoende om besparings te kwantifiseer en help om die finansiële lewensvatbaarheid van verbruikerskant-intervensies te bepaal. Die program bied ook 'n verwysingspunt vir applikasies wat besparingstudies wil implementeer.

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LIST OF SYMBOLS

ANSI	American National Standards Institute
CO_2	Carbon-dioxide
CER	Certified Emission Reduction
CDM	Cleaner Development Mechanism
CCGT	Combined Cycle Gas Turbines
CSP	Concentrated Solar Power
DSM	Demand-side Management
DoE	Department of Energy
EEDSM	Energy Efficiency and Demand-side Management
EMO	Energy Management Opportunity
ESCo	Energy Service Company
ERDM	Entity/Relational Data Model
FK	Foreign Key
GWh	Gigawatt-hour
GUI	Graphical User Interface
GHG	Greenhouse Gasses
IPP	Independent Power Producers
IT	Information Technology
IDE	Integrated Development Environment
IRP	Integrated Resource Plan
kWh	Kilowatt-hour
M&V	Measurement and Verification
MW	Megawatt
MYPD	Multi-Year Price Determination

NERSA	National Energy Regulator of South Africa
OO	Object Orientated
PV	Photovoltaic
PK	Primary Key
RAD	Rapid Application Development
R	Rand
RDMS	Relational Database Management System
RBS	Revised Balanced Scenario
SQL	Standard Query Language
UML	Unified Modelling Language
V	Voltage
W	Watt
ZARc	Cent

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1 INTRODUCTION

1.1 Overview

Climate change has become a cause of great concern during the last century, which has seen a rise in the global mean temperature. The fact that two thirds of the temperature increase occurred during the last three decades only provides further basis for alarm about climate change. The main contributing factor towards the temperature rise has been the increase in greenhouse gases. Evidence indicates that the burning of fossil fuels, critical in the supply of energy, has contributed towards three quarters of the CO_2 increase. In addition to the increased surface temperature, the world's population has reached the 7 billion mark and still continues to grow, increasing the demand for energy.

1.2 Project motivation

During 2008 South Africa reached electricity supply capacity constraints due to limited generation capacity and the lack of maintenance on generation plants. As a result, generation plants were required to operate at higher levels for prolonged periods. The economic downturn experienced in South Africa since 2008, as part of a global economic recession, relieved some of the strain placed on the electricity supply system. However, consumption levels are returning to those experienced during 2008 and no new base load power stations have been added since then.

The short-term energy capacity constraints facing South Africa can to some extent be managed by shifting the peak demand. Preventing an electricity shortage can only be achieved by adding additional capacity or reducing the overall electricity consumption. If these requirements are not met, the South African electricity supply will be placed under severe pressure, which will jeopardise supply security. Big manufacturing concerns such as mining enterprises could be disconnected from the grid during load shedding, which will have a significant effect on the economy. Political implications can also arise if the supply to neighbouring countries is reduced [1].

The supply-side solutions currently under consideration are overdue and too expensive. Demand-side solutions, on the other hand, can provide the appropriate long-term results. These solutions are aimed at increasing energy efficiency whilst reducing the demand for electricity. These solutions are readily available and less expensive to implement than supply-side solutions and there is a strong business case to be made for energy efficiency and conservation strategies [1].

The Energy Efficiency and Demand-side Management (EEDSM) programme implemented by Eskom over the past few years is widely recognised as one of the most cost-effective ways of reducing consumption, whilst meeting environmental targets in line with the objectives of the Kyoto Protocol. The EEDSM programme consists of three types of projects that are independently implemented to achieve cost reduction as well as environmental and social improvement, address reliability and network issues, and improve market conditions. These projects encompass three stakeholders: the utility, the client and the Energy Service Company (ESCo). The success of these projects relies on the fact that savings impacts can be determined to a level of accuracy and trust acceptable to all stakeholders. The process used to verify the savings impacts is known as Measurement and Verification (M&V) and is conducted by an independent party.

Critical in calculating the savings achieved with any demand-side intervention is the consumption levels before and after the interventions. In most cases it is impossible to determine with any certainty the energy consumption of the various areas within the facility.

Energy audits enable the calculation of various consumption levels and can provide the M&V practitioners with valuable insight regarding load operation and user behaviour.

1.3 Project description and objectives

Demand-side Management (DSM) is currently the most cost-effective solution for South Africa's present energy crisis. The success of DSM greatly depends on the quantification of the savings achieved by demand-side interventions. Currently these savings are difficult to quantify as the loads affected by the interventions cannot always be isolated. Figure 1.1 illustrates the ideal case where data loggers are installed for each load enabling consumption levels to be accurately determined. Such an installation will enable the exact quantification of the savings associated with demand-side interventions. However, installing data loggers on each load is both expensive and impractical to implement.

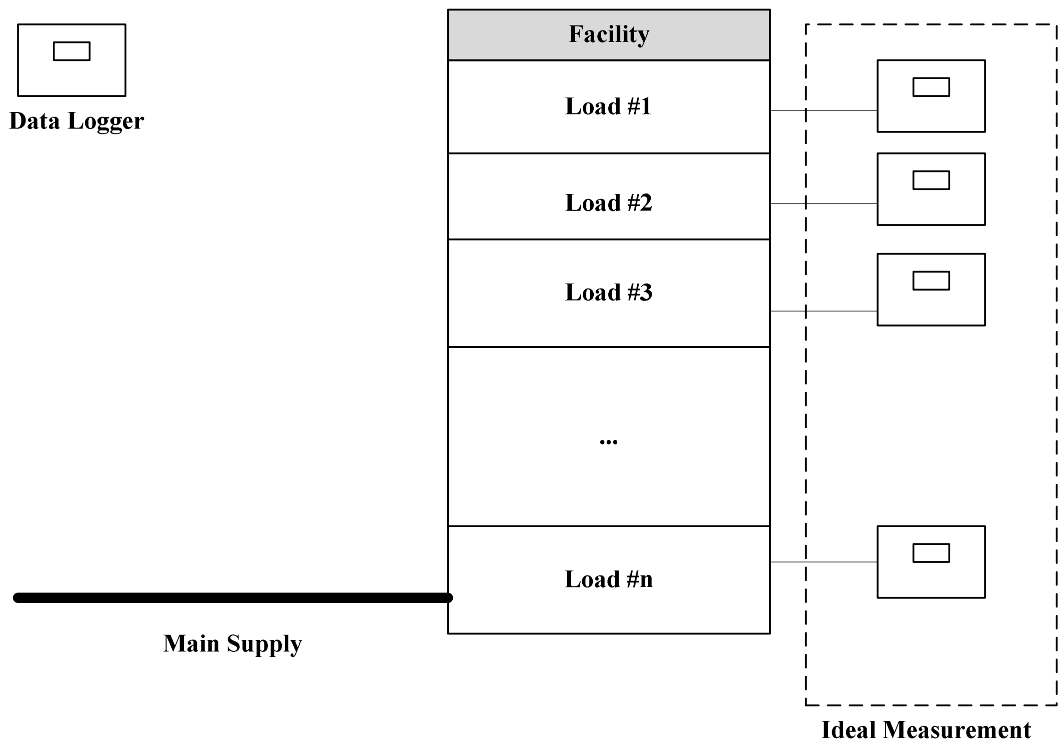

Figure 1.1: A facility consisting of multiple loads indicating the ideal measurement required to successfully quantify the savings incurred by a DSM intervention.

In order to determine the consumption of the individual loads contained in a facility, an energy audit is conducted. An energy audit consists of a load survey and an analysis. During the load survey, data regarding individual loads is collected, upon which the data is analysed to determine the consumption of the various loads. Current energy audits are conducted manually and consumption calculations are done by means of spread sheets, a time consuming and error prone process.

The application developed as part of this research project is designed to assist with the load survey process and presents a methodology for calculating consumption profiles to best simulate the actual consumption, without the need for expensive data loggers. The proposed application consists of a central database and a client-side application that provides users with remote access. Figure 1.2 shows the central database with the remote users.

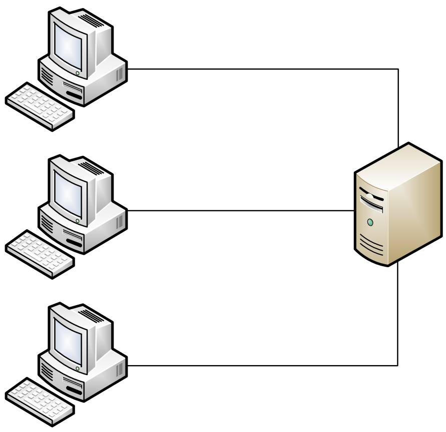

Figure 1.2: Central database with remote users.

The centralised database prevents data from being duplicated on all the users' computers, thus increasing data integrity. There was decided to make use of a relational database model as it provides structural independence by using independent tables. In addition to its structural independence, the relational model also isolates the end-user from physical details, improving management and implementations. The relational database model was implemented through the MySQL Relational Database Management System (RDBMS) as it requires no license and supports databases of any size.

The client-side application allows users to select loads from the available options which are contained in the database and is managed by a system administrator. The application was developed with the Delphi development platform. This platform provides pre-built components, drag-and-drop visual design and two-way tools that assist in keeping the visual design and source code synchronised. In addition to the environmental considerations, Delphi-generated applications have a single deployment .exe-file, requiring no additional drivers or platform based setups to be deployed (run) on a client machine.

The system is designed for commercial buildings, with the Stellenbosch University Engineering Faculty used as reference. Executing an energy audit on the complete faculty would have been an immense task and it was decided to conduct a walk-through audit of the Electrical and Electronic (E&E) Department to determine the key features in the building that could easily be retrofitted and managed to significantly reduce energy consumption. The features included in this project are:

- Heating, ventilation and cooling.
- Information Technology (IT) infrastructure.
- Lighting.

Once these key features were identified, a detailed audit was conducted on the third floor of the E&E Department, as it best represents a commercial building. In addition to the detailed audit, data loggers were installed to capture the energy consumption associated with the third floor. This acquired data was then compared with the simulated results generated by the energy auditing application. Having defined the scope of the project, the objectives could be determined:

- Develop a methodology to which an energy auditing application can be designed and implemented.
- Design a database and a client-side application to access the various tables.
- Conduct load research into *how* and *when* loads operate.
- Obtain actual consumption data and compare it to the simulated results to determine the accuracy with which the application simulates the actual consumption.
- Identify and asses an EMO.

1.4 Thesis structure

This thesis is structured into seven chapters with seven appendices. The details of the chapters are as follows:

- Chapter 2 presents the literature review of the main components of this study. The motivation for increased energy efficiency is presented along with the different stages of DSM interventions and M&V projects. Details of the energy audits are provided, followed by a discussion of the data processing protocol, the Delphi development environment and Unified Modelling Language (UML) diagrams.
- Chapter 3 highlights those aspects considered for load modulations and consumption profile computations such as the actual rating of the loads, the duty cycles and the usage profiles.
- Chapters 4 present the design considerations which were incorporated and the detailed design for the database.

- Chapter 5 presents the design considerations which were incorporated and the detailed design for the GUI.
- Chapter 6 compares the results obtained from a test case for each load with the calculated theoretical values. In addition to the individual test cases, the results of the case study are provided and compared to the actual consumption.
- Chapter 7 summarises the results of the case study, presents conclusions and gives recommendations for further work.

2 LITERATURE REVIEW

2.1 Motivation for increased energy efficiency

2.1.1 Kyoto Protocol

Since the Industrial Revolution, increased carbon emission has led to an increase in the amount of Greenhouse Gases (GHG) in the atmosphere [2]. The main drivers contributing towards the increase in GHG emissions are the increase in gross domestic product per capita and population growth. Evidence further indicates that the burning of fossil fuel has caused about three-quarters of the increase in CO_2 and is still on the up [3]. However, the burning of fossil fuel is critical for the production and supply of energy to the industries, thus the reason for global pressure on reducing GHGs through energy management.

The Kyoto Protocol, a legally binding international agreement regarding climate change, was adopted in 1997 and came into force on 16 February 2005. By committing to this agreement, nations committed themselves to the reduction of global warming and GHG by 5.2%, based on the 1990 levels, for the first period 2008 – 2012 [4].

2.1.2 Cleaner development mechanism

The purpose of the Cleaner Development Mechanism (CDM) is to assist parties not included in Annex 1 of the Kyoto Protocol to achieve their sustainable development goals while contributing to the ultimate objective of the convention. In addition, parties included in Annex 1 are assisted in achieving their emission limitation and reductions as stated in Article 3 of the protocol [4]. Under CDM:

- Parties not included in Annex 1 will benefit from project activities resulting in Certified Emission Reduction (CER).

- Parties included in Annex 1 may use CERs occurring from these project activities to contribute to their compliance with their emission limitation and reduction commitments under Article 3 of the Kyoto Protocol.

CDM projects are grouped based on project type. Figure 2.1 presents the various groups, expressed as a percentage of the total number of CDM projects [5].

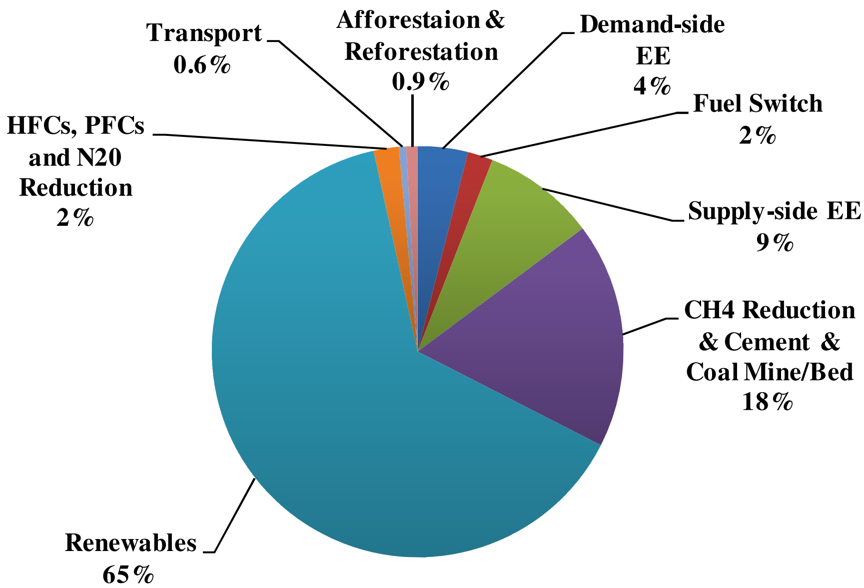

Figure 2.1: Percentage of CDM projects in the various groups [5].

Each of the CDM project groups has an expected CERs forecast for 2012. Figure 2.2 presents the CERs forecast for each project group, expressed as a percentage of the total CERs for 2012 [5].

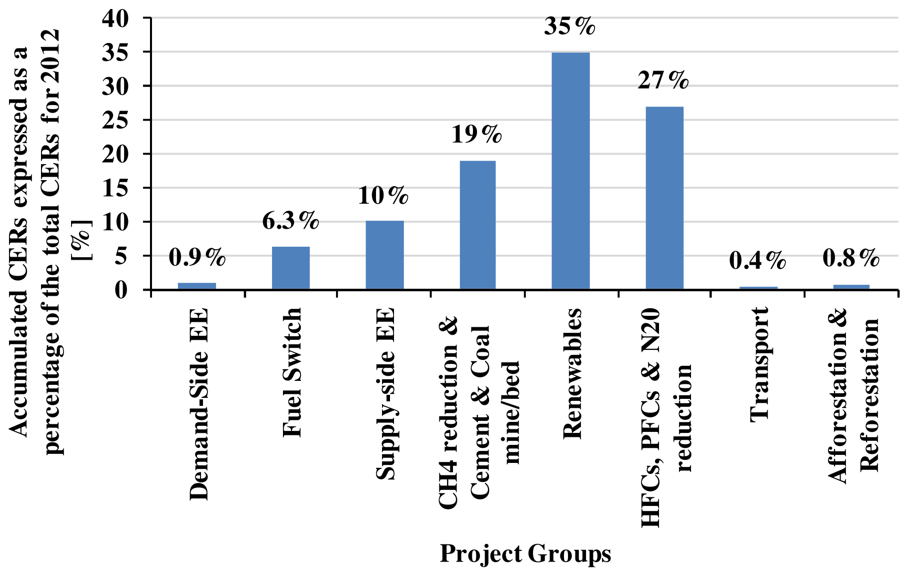

Figure 2.2: The 2012 CER's forecast for each CDM project groups [5].

Figure 2.3 presents the size and the CERs contribution per group. In the current portfolio the majority of the CERs are obtained from projects generating high volumes of CERs and little sustainable development benefits [6].

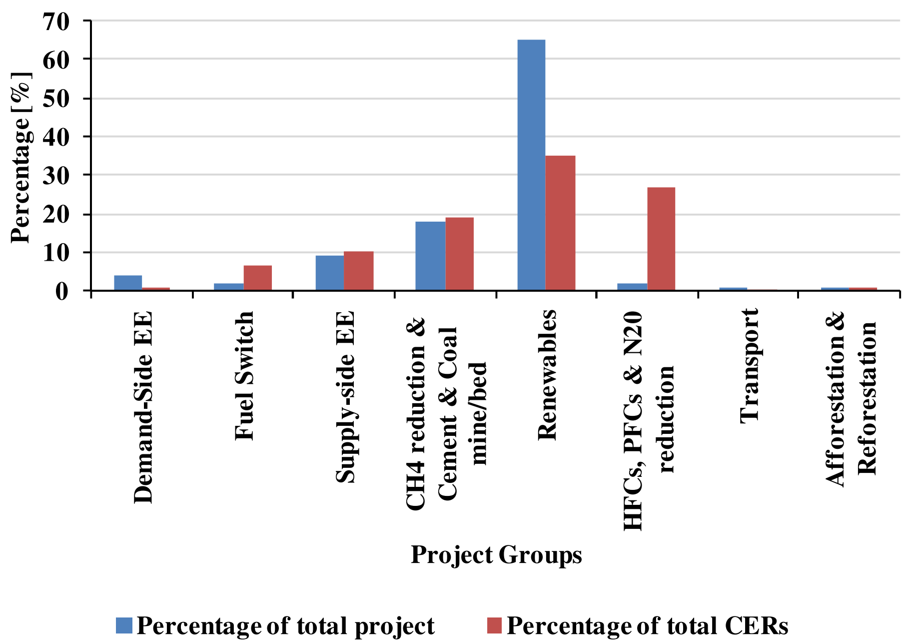

Figure 2.3: The size of and the CER's contribution for each project group [5].

Demand-side energy efficiency projects create high sustainable development benefits while reducing emissions, at a low cost. Despite these facts, demand-side energy efficiency projects are under-represented in the current cleaner development mechanism project portfolio [6]. Despite the potential, demand-side energy efficiency projects deliver low CERs per project. The low CERs per project limit the financial reward to be gained by investors. Investors only receive financial reward for CERs and not for the contribution made towards sustainable development. In addition to the low CERs, emission reduction is difficult as the reductions are dispersed and involve a number of small projects [6].

The energy efficiency market is multi-faceted, with three distinct market segments [6]:

- Discretionary retrofit, which refers to a premature decision to replace existing technology to raise energy efficiency.
- Planned replacement, which relates to replacements that would have taken place at some point.
- New installations, relating to equipment choice for new installations.

The transaction costs within a market segment remain fixed, as the costs are mostly determined by the registration, verification and certification procedures [6].

2.1.3 Local energy scenario

2.1.3.1 South Africa's current energy crisis

Eskom, the national energy provider of South Africa, implemented its first Multi-Year Price Determination (MYPD 1) from 1 April 2006 to 31 March 2009. The forecasted sales, average electricity prices and annual percentage increases that were approved by the National Energy Regulator of South Africa (NERSA) for the period defined by the MYPD 1, are presented in Table 2.1 [7].

Table 2.1: MYPD1 as approved by NERSA [7].

	2006/07	2007/08	2008/09
Allowed revenues from tariff based sales [R'm]	36 693	40 084	44 504
Forecast sales to tariff customer [GWh]	179 277	186 443	192 511
Standard average price [ZARc/kWh]	17.91	18.09	18.27
Percentage price increase [%] on the standard average price	5.1	5.9	6.2

Included in the MYPD 1 were inflationary increases for cost of supply, such as Primary Energy (PE), manpower and additional operating costs, together with the capital cost for the construction of two coal-fired power stations, Medupi and Kusile, including the associated transmission and distribution infrastructure. The cost was estimated at R 97 billion, with the cost of a single power station estimated at about R 33 billion.

In March 2007, Eskom applied for a revision of the 2007/08 price increase as stipulated in the MYPD 1. Eskom requested an increase from 5.9% to 18.7%, mainly due to increases in the cost of supply. The assumptions made that costs would follow an inflationary increase were incorrect. Supply costs alone showed an increase of 18%, 12% higher than the estimated inflationary 6%. In addition to the increases in the supply costs, the construction costs of both power stations increased from R 97 billion to R 150 billion. The estimated cost of each power station increased to R 66 billion [7].

The construction cost of the two power stations continued to increase, with an estimated unit cost of R 120 billion – a 363% increase during the MYPD 1 control period. The increased construction cost forced Eskom to re-apply for a revision of the 2008/09 price increase in December 2007. NERSA granted Eskom an additional increase of 13.3% in June 2008, resulting in a total average price increase of 27.5% for the 2008/09 financial year.

Eskom did not submit an MYPD for 2009/10 and 2011/12 as the funding model for the capital expansions was being finalised. Instead, Eskom applied for a 34% interim increase during May 2009 for the 2009/10 financial year, upon which NERSA approved a 31.3% increase.

On 30 September 2009, NERSA received Eskom's MYPD for 2010/11 – 2012/13 (MYPD 2), requesting an annual price increase of 45% per annum over the MYPD 2 control period. The required increase was reduced to 35% by 30 November 2009. NERSA finalised the increases depicted in the MYPD 2, for the control period 2010/11 – 2012/13, by 24 February 2010. Table 2.2 presents the increases.

Table 2.2: MYPD 2 as approved by NERSA [7].

	2010/11	2011/12	2012/13
Allowed revenues from tariff based sales [R'm]	85 180	109 948	141 411
Forecast sales to tariff customer [GWh]	204 551	210 219	214 737
Standard average price [ZARc/kWh]	41.57	52.30	65.85
Percentage price increase [%] on the standard average price	24.8	25.8	25.9

The reduction in the annual increase from 45% to 35%, presented by Eskom on 30 November 2009, included a number of provisions [8]:

- A 13% increase per annum for both 2013 and 2014.
- A delay in the construction programme of the Kusile coal-fired power station.
- A delay in the 100 MW Sere wind farm and 200 MW of concentrated solar power (CSP) plant.
- Re-phasing of certain other new build projects and contracts.
- Introduction of more Independent Power Producers (IPP) options in later years (after the MYPD 2 period).
- Finding a 30% to 50% private equity partner for Kusile.

- Removing Eskom's responsibility to fund the next coal-fired power station (Coal 3) and the nuclear build program.

In addition to the MYPD, the Department of Energy initiated the Integrated Resource Plan (IRP). This report provides a layout of the proposed new build projects to increase the generation capabilities of South Africa for the period 2010 to 2030 with the scenarios being derived based on the cost-optimal solution for these projects. These options where then balanced in accordance with qualitative measures such as local job creation [9].

The second round of public participation was conducted in November and December 2010, which led to a review of certain policies contained in the Revised Balanced Scenarios (RBS). Following these policy recommendations, the following changes were made, resulting in the policy-adjusted IRP [9]:

- Solar photovoltaic (PV) was included as a separate technology, with an assumed roll-out of 300 MW per year from 2012.
- Coal generation, only expected after 2026, was moved forward, allowing for imported coal options.
- A minimum of 711 MW will be added from combined cycle gas turbines (CCGT) between 2019 and 2021, improving security of supply and providing back-up to the renewable energy roll-out.
- Cost optimisation will be implemented on import hydroelectricity, leading to cost reduction (due to the increased renewable roll-out and bringing coal generation forward).
- Modifications are to be made to the roll-out of wind and concentrated solar power (CSP) to accommodate the solar PV options. The previous renewable groupings will also be completely disaggregated into constituent technologies: wind, CSP and solar PV.

Figure 2.4 presents the comparison of the scenarios before and after the consultation process.

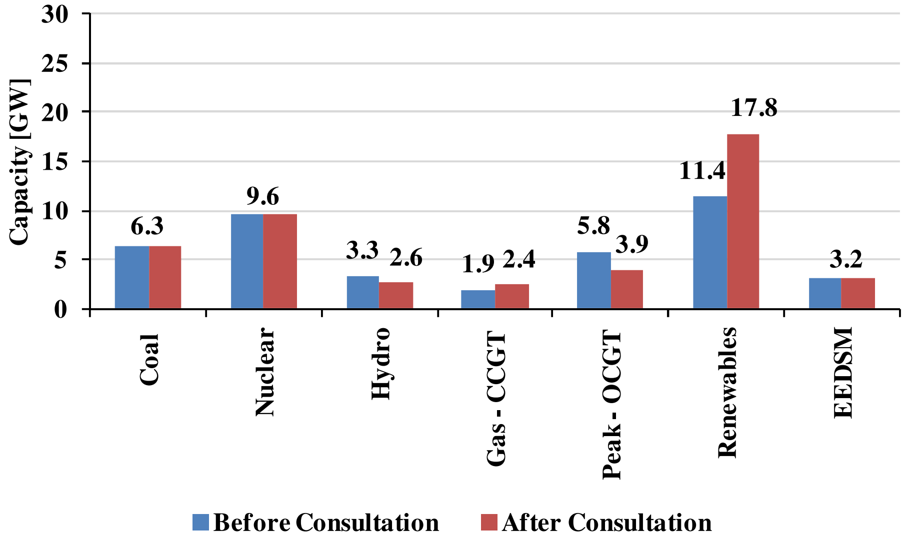

Figure 2.4: Comparison of scenarios before and after the consultation process [9].

In the IRP, the assumptions towards the EEDSM were kept conservative. No new projects were considered. However, most supply-side solutions are being pursued in order to relieve the strain on the energy supply. These solutions are too late and expensive. Demand-side solutions are more readily available and are less expensive, and are thus able to decrease the current demand in a relative short period of time [1].

2.1.3.2 Demand-side management

The current electricity shortfall facing South Africa was brought on by insufficient generation supply relative to growing demand, maintenance closure and unplanned generator outages. Understanding the cause of the electricity shortfall is critical in determining the measures to be applied. Electricity shortfalls (or constraints) can be divided into two broad categories: energy and capacity. Table 2.3 presents these constraints [10].

Table 2.3: The categories of constraint for electricity [10].

Constraint	Definition	Causes
Capacity	Functioning infrastructure is insufficient to meet demand during peak hours.	- Plant breakdown - Loss of transmission/distribution capacity - Growth in peak demand outstrips capacity
Energy	Demand exceeds energy input available for electricity generation.	Fuel or supply disruption

Figure 2.5 and Figure 2.6 indicate that South Africa is facing an energy constraint due to an increased demand and insufficient investing in the infrastructure. Solving this problem requires a range of both demand-side and supply-side solutions [10]. Supply-side responses primarily involve increasing generation capacity and its availability, while demand-side responses aim to reduce the quantity of electricity being consumed [11].

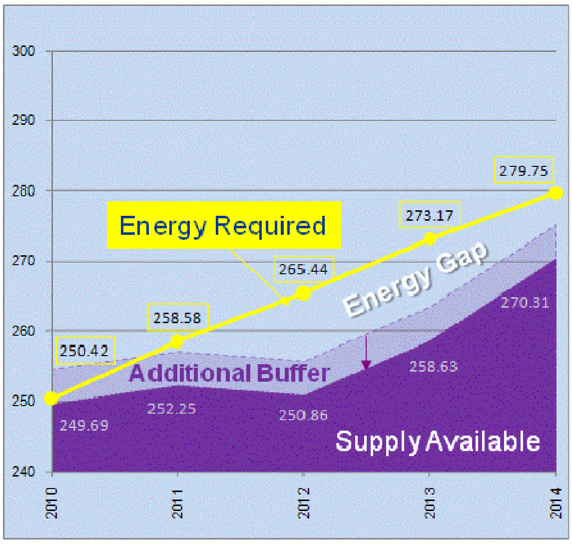

Figure 2.5: Energy availability vs. energy required [1].

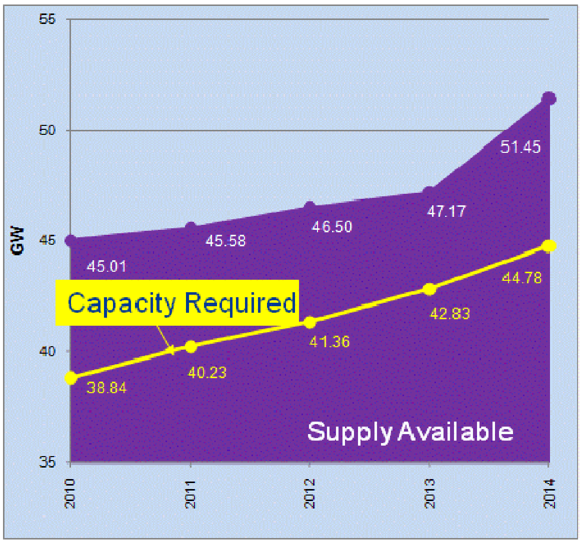

Figure 2.6: Capacity available vs. capacity required [1].

Since 2004, EEDSM has gained stature and is recognised as one of the most cost-effective ways of reducing the electricity demand and meeting environmental targets [12].

2.2 Energy efficiency and demand-side management

2.2.1 Overview

DSM projects are implemented to achieve the following results [13]:

- *Cost reduction:* DSM projects assist in reducing the energy demand required.
- *Environmental and social improvement:* The energy reduction due to DSM project lead to reduced GHG emissions.
- *Reliability and network issues:* Preventing network problems through demand reduction, in ways that maintain the system's reliability in the short-term and prevent expansion in the long term.
- *Improved markets:* Short-term response to market conditions, especially during times of high market prices caused by reduced generation or network capacity.

The above mentioned outcomes can be reached through three main types of projects [13]:

- *Energy reduction*: Demand is reduced through more efficient equipment, buildings or processes.
- *Load management programmes*: The load pattern is altered by shifting the load away from peak times.

The focus of this thesis is on the implementation of energy reduction projects, as South Africa is facing an energy constraint and requires sustainable, long-term solutions.

Successful DSM projects rest on the fact that impacts can be determined to a degree of accuracy and trust that is acceptable to all stakeholders. This process is known as M&V. The objective is to provide an impersonal, credible, transparent and replicable process that can be used to quantify and assess the impacts and sustainability of EEDSM projects.

DSM projects encapsulate a number of stake holders which include the utility (in this case Eskom), the client and the Energy Service Company (ESCo). Figure 2.7 illustrates the interaction between the various stakeholders [14].

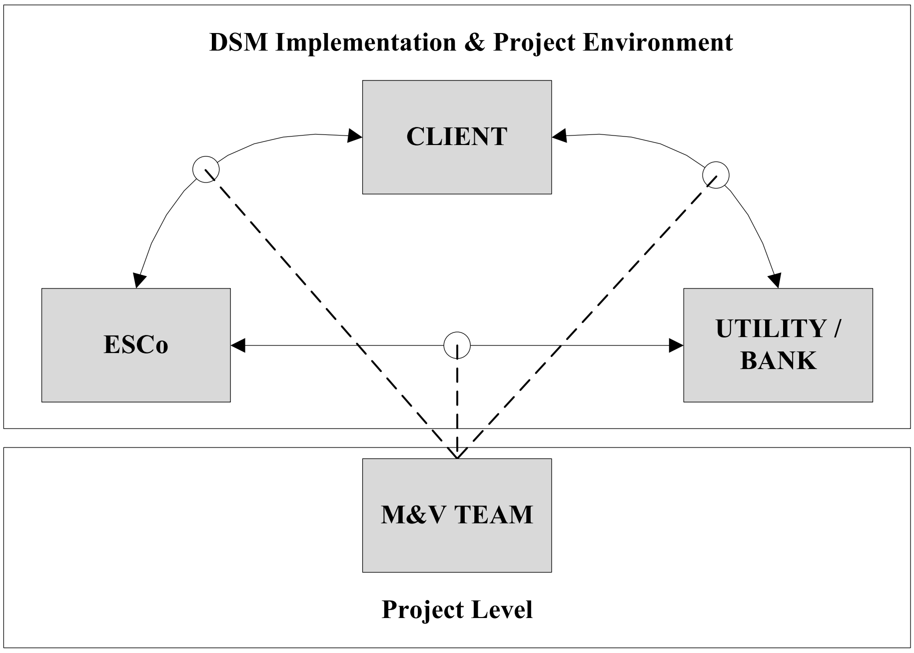

Figure 2.7: The interaction between the various DSM project stakeholders [14].

The client wants to reduce monthly energy costs by reducing either peak demand and/or energy consumption. The ESCo wants to implement the DSM project and receive payment for services rendered, while Eskom wants to protect its investment in the DSM project. This situation asks for an independent third party to verify the impacts to a level of accuracy that is acceptable for all stakeholders.

During the preliminary and design phase of the DSM project, either the ESCo or the client identifies a potential project and performs a savings calculation. After the initial phase, a proposal is submitted to Eskom by the ESCo to obtain funding for the project. Once the funding has been approved, the ESCo can proceed with implementation of the project. After the DSM intervention, the primary questions that all the stakeholders want answered, are: How much are we saving, and are the savings sustainable?

The dynamics of the EEDSM projects make it difficult and certainly not preferable to assign any of the principal stakeholders to deliver an objective assessment of the savings. The quantification and assessment of the savings must remain objective and the complete process must be transparent. The long-term success of many projects is often hampered by the inability of project partners to agree on the savings that have been obtained. It is for this reason that a third party is included in the process to determine and verify the savings, hence the M&V team.

In the remainder of this section, the DSM project stages as well as the M&V project stages are discussed.

2.2.2 Demand-side management project stages

There are various stages in a DSM project to which an ESCo must adhere when implementing a DSM project. Depending on the project type, the details of the various stages can vary, but one or another form of a stage will be included. Figure 2.8 presents the stages, while a conceptual representation of the impact on a system's electrical demand is given in Figure 2.9 thereafter [14].

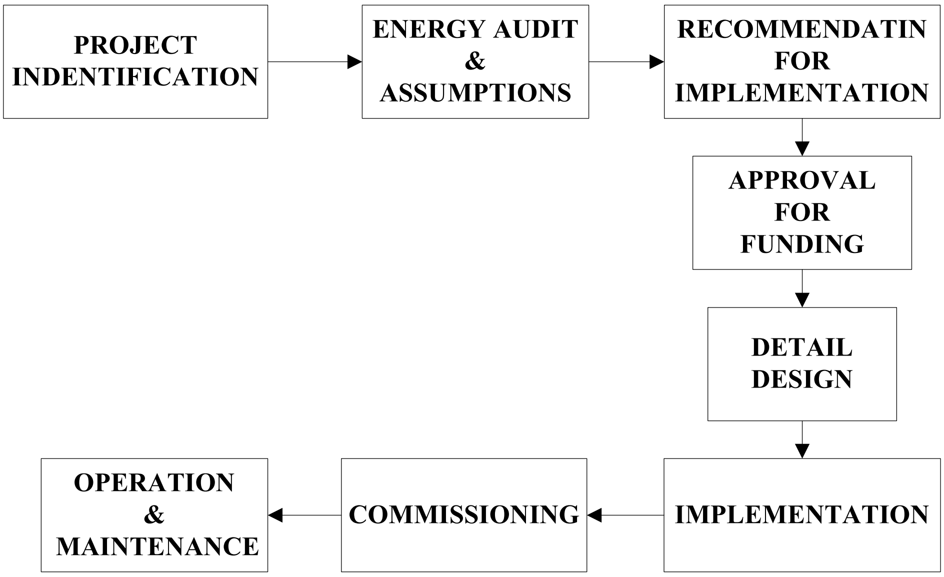

Figure 2.8: DSM project stages [14].

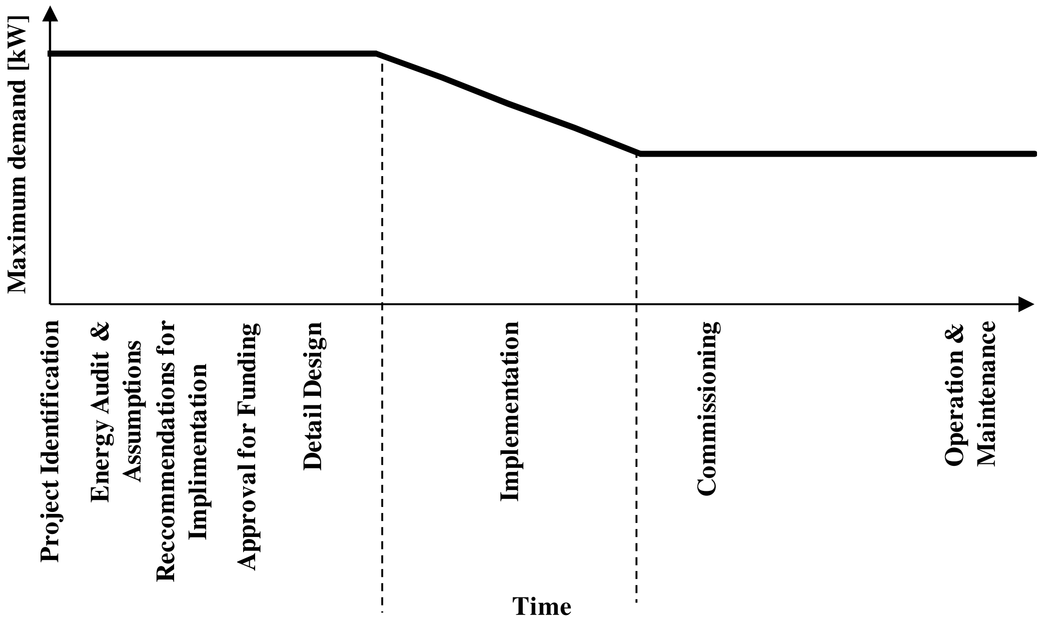

Figure 2.9: Conceptual presentation of the impact of the various stages on the system's electrical demand [14].

2.2.2.1 Project identification

The need, potential or opportunity for DSM savings is identified by either the client or the ESCo. After the opportunity has been identified, an ESCo is contracted to determine the potential impacts and savings. The quantification of these impacts and savings assist the

ESCos in evaluating the project's financial viability. After the evaluation, an application is sent to the utility, requesting DSM funding. Accompanying this application will be a letter of intent, provided by the client [14].

2.2.2.2 Energy audit and assumptions

After the ESCo determined the potential savings that can be achieved with the DSM intervention identified, an energy audit is conducted on the facility to determine the current consumption levels. This audit determines the type, quantity and rating of all relevant energy systems and usually consists of a walk-through audit followed by a detailed audit. Assumptions, made during the detailed audit, regarding unavailable system information are also presented.

2.2.2.3 Recommendation for implementation

After all the system information is gathered, a feasibility study is conducted for all DSM activities. The DSM activities that show the greatest potential are selected and the ESCo presents its findings to the client. The client then evaluates the feasibility and decides whether to continue with the project or not. Once the client approves, a proposal is submitted to the utility to qualify for DSM funding.

2.2.2.4 Approval for funding

Once the utility establishes that the proposed DSM activities will deliver satisfactory results within an acceptable budget, timeframe and risk level, funding is granted.

2.2.2.5 Detail design

Once funding has been granted, a detail design of the DSM interventions is made by the ESCo.

2.2.2.6 Implementation

The DSM activities are implemented based on the detailed plan designed by the ESCo and is characterised by a fluctuation in the client's energy usage. During the implementation stage of the project the M&V team and the utility are notified and the utility issues a completion certificate after the completion of the project. The completion of this stage signals the performance assessment stage of the M&V process.

2.2.2.7 Commissioning

Commissioning is done after installation to ensure that the implementation was done correctly and that the equipment and systems are performing to the specified requirements. After commissioning, a report is compiled and submitted to the client.

2.2.2.8 Operation and maintenance

The DSM measures need to be maintained to ensure that the DSM activities deliver the same level of performance as during the commissioning stage of the project and that maximum demand, consumption and energy cost are continually reduced. In the case where performance levels are not met, the responsible authority is held accountable as per contractual agreement with the utility.

2.2.3 M&V project stages

The stakeholders in the M&V process are the M&V team, the client, the Utility and the ESCo. These stakeholders provide valuable information to the M&V project and give buy-in to the M&V team throughout the various project stages. The deliverables produced by the M&V projects are the following:

- M&V scoping report.
- M&V plan (which requires acceptance from both ESCo and client).

- M&V baseline report (which requires acceptance from the ESCo).
- Post-implementation M&V report.
- Performance assessment report(s) & performance certificate.
- Performance tracking reports (monthly, annual, or agreed interval).

Figure 2.10 presents the interaction between the M&V and DSM projects, followed by a description of each deliverable in the remainder of the section [14].

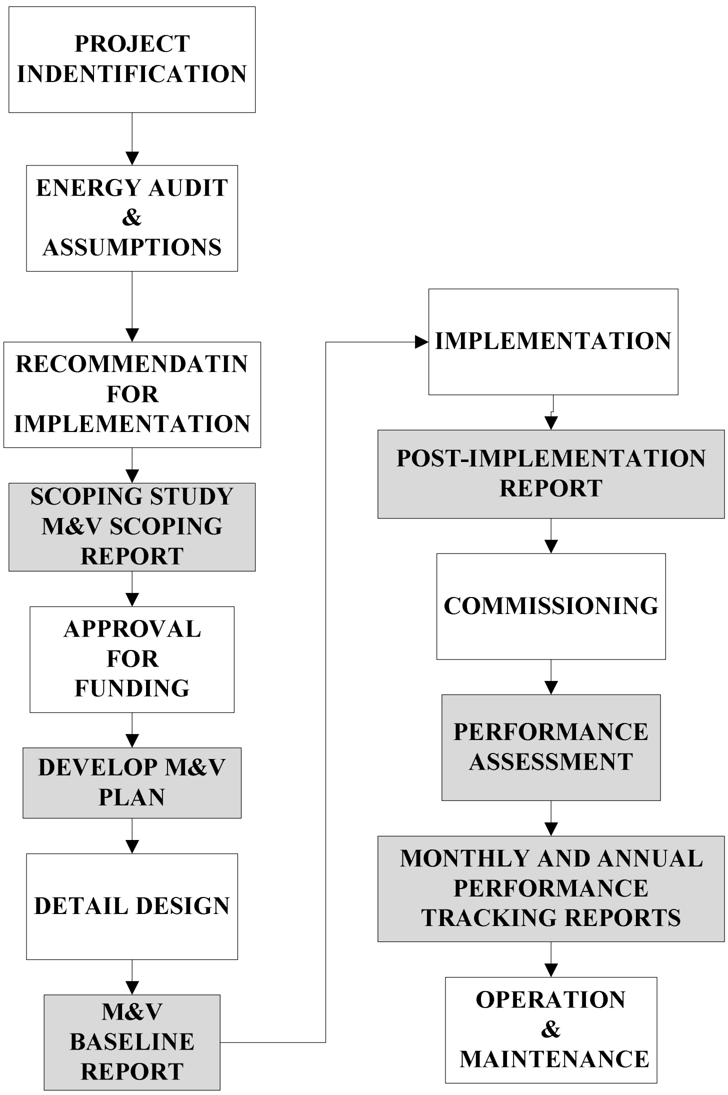

Figure 2.10: DSM and M&V interaction [14].

2.2.3.1 M&V Scoping Report

Once Eskom approves a DSM project, the M&V team is instructed to proceed with their measurement and verification activities. The team gathers all relevant and available data on the project in order to obtain a clear understanding of what the DSM project entails and produces the scoping report. The compiled report is important to the utility as it provides the expected impacts of the project. In addition, any misunderstandings between the client and the ESCo in terms of the proposed DSM activities are also outlined.

2.2.3.2 M&V plan

The M&V plan is the first deliverable and must be accepted by the ESCo and the client. It forms the backbone of the whole M&V process and describes the procedures and activities that will be followed to measure and verify the DSM interventions. The scoping report is included to ensure a "stand-alone" report that provides a complete overview of the project.

2.2.3.3 M&V baseline report

Once the M&V plan has been accepted by the ESCo and the client, pre-implementation measures are used to develop the baseline. The baseline report must contain the actual baseline consumption as obtained during the detailed audit of the facility and will be used during saving calculations. The final report will only be delivered after all parties have met and are in mutual agreement about the developed baselines.

2.2.3.4 Post-implementation report

The M&V team conducts a post-implementation audit, prior to the commissioning of the equipment and system, to verify that the implementation has taken place as specified. The actual energy consumption is also measured and then subtracted from the pre-implementation baseline to obtain the savings brought about by the DSM intervention.

2.2.3.5 Performance assessment

This stage allows for the ESCo to make adjustments to the applied intervention, to ensure that the project deliverables are met. The assessment is typically done over a three month period, but this can vary depending on contractual agreements. In the case where the DSM intervention delivers less than the contacted impacts, the ESCo will be held liable and penalties may be paid to the utility. The contracted DSM targets will then be adjusted to reflect the actual values, before the M&V process continues.

2.2.3.6 Performance tracking reports

These reports serve as a summary for a specific period and include all the monthly data and performance tracking reports available.

2.3 Energy audits

Energy auditing is the application of the first law of thermodynamics, called the law of conservation of energy. This law provides the background for the construction of energy balances, a process during which the energy consumption systems are identified and quantified [15]. This is necessary, as the energy consumption data of most enterprises is limited to a few utility bills and the consumption of different sections, buildings and departments are rarely known [13]. In this situation, it is impossible to determine with any certainty the energy performance of the different departments.

Energy audits are critical in determining the current consumption situation and usually precede a DSM project. However, energy audits can also be performed at any time during the program's lifetime to verify and uncover energy efficiency opportunities [16].

The activity of an energy audit can be defined as "a process to evaluate where a building or plant uses energy and the identification of opportunities to reduce consumption" [17].

The scope, calculations and the level of economic calculations are all aspects of an energy audit, and will be handled differently by each individual. The cost of an audit is directly related to how much data is collected and analysed as well as the number of conservation opportunities identified. Thus, the cost of the audit will determine the type of audit performed. The two types or levels of auditing are presented in order of increasing complexity [17]:

- *Walk-Trough Audit*: This is a tour of the facility during which the energy system is visually inspected and the auditor uses only data that is already available in the facility. This audit can be completed in a short time, is the least expensive and provides low-cost improvement measures that can be implemented. This audit will also provide recommendations for the scope of the detailed audit, if it is justified.
- *Detailed Audit*: This audit quantifies energy uses and losses through a more detailed review and analysis of equipment, systems and operational characteristics. On-site measurement and testing may be included to assist in the quantification of energy usage and load efficiency. Although instruments are needed, it does not mean that auditing is an exact science and auditors must still use their experience and judgement in collecting and interpreting data. The measurements required for each detailed audit varies, but about half of the effort is spent collecting data while the other half is spent analysing the data and preparing the report.

While audits provide an insight into the consumption of the facility, they have their limitations. Audits are labour intensive and require large amounts of data, while providing a static picture of one particular moment in time. An audit should therefore be considered as the start of a continuous process of data collection and performance analysis. The results gained from one time period to the next can then be compared to identify trends in energy efficiency.

2.3.1 The audit process

Once the type of audit has been chosen, the structural and mechanical information can be collected. A thorough evaluation of the energy usage systems should be conducted prior to the site visit, as it will aid with the identification of areas showing potential savings and help to make the best of the time on-site. Below are the key steps, followed by an illustration in Figure 2.11, that are to be taken after the initial client meeting and the historical data analysis [17]:

- *Preliminary walk-through audit*: To assess the general condition and current system operations relevant to energy efficiency and mark-up any potential improvement or factors to be considered later on in the audit.
- *Analyse energy consumption and costs*: Gather, summarise and analyse the historical billings and applicable tariffs.
- *Compare analysis:* Calculate the Energy Use Index (EUI) and compare this to the EUIs of similar buildings. This comparison will be a good indicator of the relative potential for energy savings.
- *Determine audit mandate:* Confirm client commitment to the audit and discuss the desired outcomes of the detailed audit.
- *Define audit scope:* Identify the energy systems to be audited.
- *Analyse energy use patterns:* Verify the times of energy use.
- *Inventory energy use*: List energy consuming loads and calculate their consumption and demand characteristics.
- *Identify EMOs*: This includes the DSM opportunities available for implementation.

- *Assess the benefits*: Calculate the potential savings to be made for each intervention and compare to the expected cost.
- *Report for action*: Report findings and suggest methods of implementation.

The steps presented above are applicable to a detailed audit. However, the process applies to walk-through audits as well but with adjustments made to certain steps.

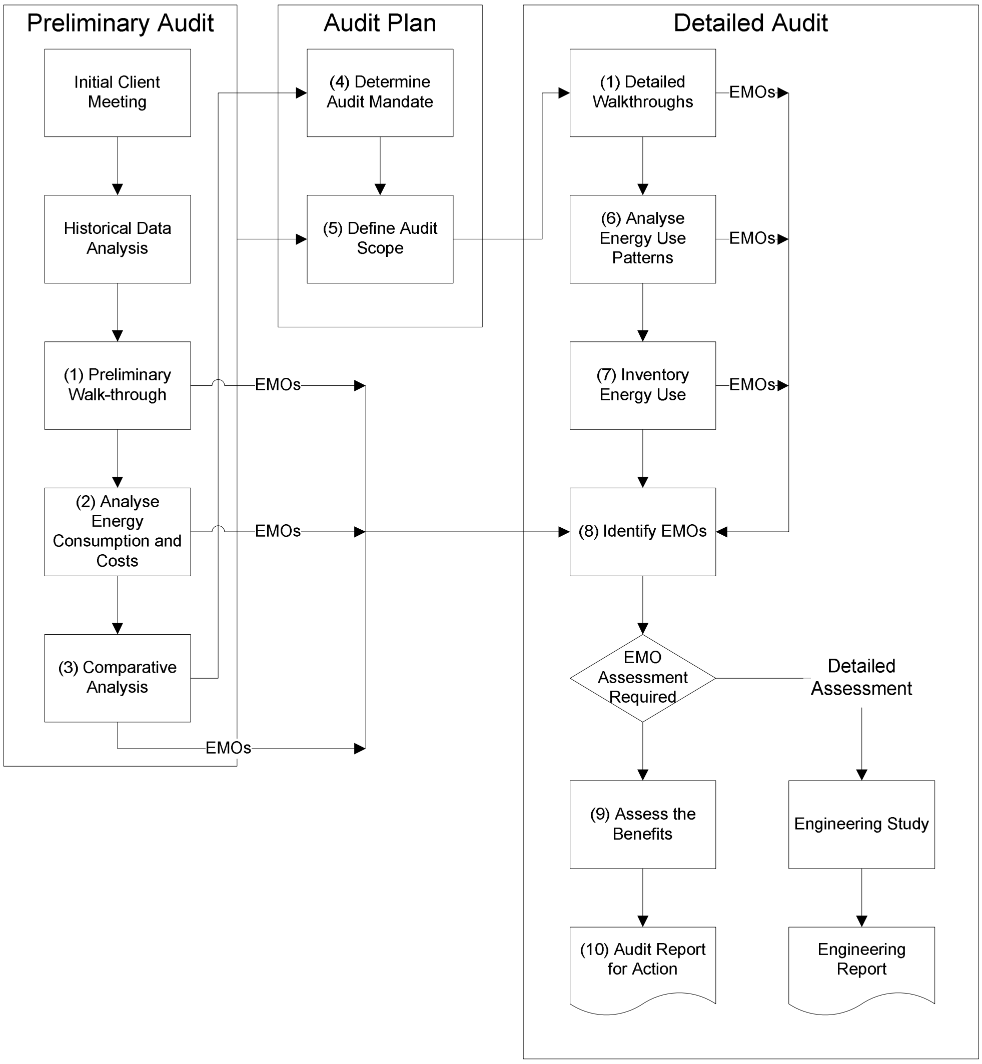

Figure 2.11: Detailed audit process [18].

2.4 Data processing

2.4.1 Overview

To understand what drives data processing, one needs to distinguish between data and information. Data refers to a collection of raw data, while information refers to processed data, from which interpretations can be made. In computer science, data processing is the analysis and organisation of data by the use of computer programs. It can be as simple as organising data to reveal patterns or as complex as making forecasts or drawing inferences using statistical modelling. Data processing can be divided in to two types, namely database processing and transaction processing. A database is a collection of records that can be searched, accessed and modified. In database processing, a central source of data is used for the computations. Transaction processing, on the other hand, refers to the interactions between two computers where one initiates the transaction while the other provides the required data. Most modern-day data processing systems use a central database, where the database is accessed and updated through transactions, executed as required by the users [19].

2.4.1.1 The data processing cycle

The data processing cycle is the chain of events present in most data processing applications. Data is first recorded and then transmitted to a computer, where the data is processed. The processing operations can include accessing and updating a database as well as creating or modifying information. After processing the data, the computer presents the user with a report of the requested results. As data is processed, modifications are stored, either to a file system or a database system to be retrieved at a later stage [19].

2.4.1.2 The file system

In the conventional file system, every user has to be allocated a set of files. Table 2.4 illustrates a conventional file system in a multi-user environment.

Table 2.4: Input files required by users [19].

User	Input
User #1	File 1; File 2; File 3
User #2	File 1; File 2; File 3
User #3	File 1, File 2; File 3

From Table 2.4 above, it is evident that files are duplicated for each of the users. This file duplication comes with the disadvantages of implementing a file system in a multi-user environment. Some of the main disadvantages of a file system are listed below [19]:

- *Data redundancy and inconsistency*: Since each user requires the same set of files to execute the desired function, files are duplicated for each user. In additional to the file duplication, information contained within files can also be duplicated by the various users. This data redundancy leads to higher storage and access cost and can also lead to inconsistencies in the data between the various users.
- *Difficulty in accessing data*: Conventional file systems do not allow for efficient data retrieval. If a request was not anticipated during the application development, there is no function that can retrieve the information requested. The only manner in which this information can be acquired is by manual extraction or by the redesign of the application.
- *Concurrent access anomalies*: In order to improve overall performance, a system can allow multiple users to update data simultaneously. In such an environment, interaction of concurrent updates may result in inconsistent data.

- *Security problem:* Not all users using the application should be allowed to access all data contained in the files. In a delocalised environment it is difficult to enforce such security constraints.
- *Integrity problems:* Data stored in files must adhere to constraints that are enforced by code in the application. When new constraints are added to applications, it is difficult to apply the changes across several applications, all with varying file structures.

2.4.1.3 The database system

A database is a collection of data, stored in a computer and contained in a table format which can be used and viewed. The Database Management System (DBMS) consists of a collection of interrelated data and a set of programs that assist in the retrieving and storing of data. Databases are designed to manage large data sets and provide safety to the data stored in the case of a malfunction or unauthorised access. In a multi-user environment, the DBMS is assigned the task of maintaining the consistency of the database. A database is thus a way to consolidate data centrally and ensure better control over the data. The advantages associated with a centralised system are the following [19]:

- *It reduces redundancy*: A file system requires each user to have a set of files and is eliminated with a centralised system.
- *Inconsistency can be avoided*: When data is stored to the files in a file system, changes are not propagated to all the other users' computers, resulting in duplicate entries. Data duplication gives rise to inconsistencies in the data.
- *The data can be shared*: Data stored by one user can be used by another.
- *Standards can be enforced*: With central control of the database, the administrator can ensure that all applicable standards are met.

- *Security can be enforced*: The database administrator can define authorisation checks, limiting the access of the various users.
- *Integrity can be maintained*: Centralised control helps the administrator to define the integrity constraints implemented on the data, while ensuring that the data in the database is accurate.

2.4.1.4 Comparison of the file and database system

The energy auditing application requires a data processing platform. This section compares the file and database systems to determine the system most suitable for the application [19]:

- A database can be seen as a collection of related *tables*, whereas a file system is a collection of related *records*.
- The database management system allows users access to a single *table* at a time, where a file management system allows access to a single *file* at a time. Note that files accommodated by the file management system have no relation to other files.
- The DBMS provides both physical and logical access to the database, enabling users to navigate through records contained within the tables. File systems provide only physical access to files, not allowing users to navigate through the records contained within the files.
- With the database being central, data is not duplicated as with a file system.
- The DBMS provides the user with flexibility in the queries that can be executed on the database, while file systems only allow for pre-determined access.
- DBMSs co-ordinate and permit multi-user access to data, where file systems are more restrictive.

- In a database, all records are identified by a unique key or index. This key allows the user to select data from multiple tables to produce the desired results. A file system does not have any indexing capabilities, which prevents data searches from being executed.

With the above mentioned comparison taken into account, it was decided to build the energy auditing application based on a centralised database system.

2.4.2 Database concepts

The theoretical foundation for how the data is stored, organised and manipulated within the database, is determined by the database model which also enables usage requirements. The database models and the DBMSs are discussed in this section, together with general database terminology.

2.4.2.1 Database models

A database model is not only a way of structuring a database; it also defines the activities that can be executed in the database. Several models have been identified, such as hierarchical, network, relational and entity/relational. These models are discussed below.

- The *hierarchical model* can be diagrammed as an inverted tree with a single table as the root. The relationships are implemented by a parent/child relationship where every parent can be associated with multiple children, a one-to-many (1:*m*) relationship. The associations are implemented through pointers, which require the user to work through the data, starting at the root, to get to the required data. The advantage of a hierarchical model is that data can be accessed quickly, as the relation is pre-defined between the tables. Another advantage is that the referential integrity is built in and automatically enforced by requiring that a child must be linked to a parent. The disadvantage of the hierarchical model is that no child table can be added that is unrelated to any record in a parent table [20].

- A *network model* is similar to the hierarchical model, but allows for a child node to have multiple parent nodes. One advantage of the network model is that it allows for faster data access than the hierarchical model, but on the down side it also requires the user to be familiar with the structure. Alterations are difficult and cannot be made without affecting the application programs [20].
- In a *relational model* database, data is stored as relations. Each relation consists of tables, records and fields. The order of the records and fields in a table is immaterial and each record in the table is identified by a field containing a unique value. These two characteristics allow the user to obtain any record without knowing the physical location of the record. This is unlike the hierarchical and network models, where the user is required to know the layout of the structures in order to retrieve the data. The relational model categorises relationships as one-to-one (1:1), 1:*m* and many-to-many (*m*:*m*) and the relationships are established by matching values of a shared field. If a user is familiar with the relationships existing between tables, any data can be accessed from tables that are directly or indirectly related [21].

  The implementation of the data model through an RDBMS makes it easy to understand and implement, while hiding the complexity of the model from the user. The RDBMS also aids the user by presenting the relational model as a collection of tables in which data is stored.

- The increasing requirement for more complex data representation has necessitated the further development of the relational model, resulting in the *Entity/Relational Data Model* (ERDM). This model adds many of the object orientated (OO) features to the simpler relational database structure, giving birth to relational databases that support OO features such as objects, extensible data types based on classes and inheritance [22].

The relational database was chosen as the model to be implemented, as it provides the following features [22]:

- Structural independence is achieved by using independent tables, which can be altered independently.
- The tabular view improves conceptual simplicity, promoting easier database design, implementation, management and use.
- Ad hoc query capabilities are based on Standard Query Language (SQL).
- Powerful RDBMSs isolates the end-user from physical derails, improving management and implementation.

2.4.2.2 Database management systems

The DBMS is complex and enables the user to input, share, edit, manipulate and display the data contained within the database. The main objectives of a DBMS are:

- *Data availability*: Data is made available to a variety of users in a meaningful format and at reasonable cost.
- *Data integrity*: The reliability of the data within the database.
- *Data security*: Users' access to the data (in the case where two users access particular data at the same time, the DBMS must prevent conflicting changes).

There are several DBMSs that are specifically designed to handle relational databases and are referred to as RDBMSs. Table 2.5 presents the compatibility, performance and range of features of each RDMS, followed by a description of each RDBMS [23].

Table 2.5: Comparison of six popular database platforms [18].

	Compatibility	Latest Release Date	Interface	Max DB Size	Max Char Size	Max Number Size
Oracle	Windows, Mac OS X, Linux	09/2009	GUI & SQL	Unlimited	4000 B	126 bits
MySQL	Windows, Mac OS X, Linux	02/2010	SQL	Unlimited	64 KB	64 bits
PostgreSQL	Windows, Mac OS X, Linux	03/2010	SQL	Unlimited	1 GB	Unlimited
DB2	Windows, Mac OS X, Linux	04/2009	GUI & SQL	512 TB	32 KB	64 bits
MS SQL Server	Windows	04/2010	GUI & SQL	524,258 TB	2 GB	126 bits

- *MySQL*: Is a widely used open source RDBMS that provides the user with a full-featured DBMS. It is compatible with a variety of operating systems, including most Linux variants; a slimmer feature set also improves performance.
- *DB2*: From IBM; runs on PC's and large mainframes; and is compatible with various operating systems, even Linux. DB2 is widely encountered, especially in companies with an extensive IBM investment.
- *PostgreSQL*: Is open-source and the most feature rich RDBMS. MySQL is known as a fast RDBMS, while PostgreSQL is known for its support of American National Standards Institute (ANSI) standards and robust processing capabilities. Even with all the features included in PostgreSQL, it still runs on most operating systems and hardware platforms.
- *Oracle*: The foremost RDBMS in the commercial market runs on several operating systems and hardware platforms. With Oracle's dependable design, it has become the preferred choice for many users.
- *MS SQL Server*: Is limited to the Windows operating system, is user friendly and has a comprehensive feature set.

The RDBMS chosen for this project's implementations is MySQL, as it accommodates databases of any size and requires no licence. The slimmer features and higher performance made it the preferred choice to PostgreSQL.

SQL, a programming language designed for the managing of data in RDBMS, greatly simplifies the data retrieval. SQL also provides users with commands that enable them to insert data, execute queries, update and delete database entries, create and modify schemas and enabled access control [18].

2.4.2.3 Database terminology

There are a few key concepts associated with relational database design. These concepts, together with a description of each, are listed below [20]:

- A *table* contains the data.
- A *field (also known as an attribute* presents a characteristic of the subject of the table to which it belongs.
- A *record* presents a unique entry (*row*) in a table.
- A *view* is a virtual table composed of records from one or more tables.
- A *query* is an expression which enables a user to search for, sort and retrieve specified data.
- *Values* are the data for each field contained in a record – equivalent to that of a *cell* in an Excel spread sheet.
- A *primary key (PK)* uniquely identifies each record within a table and enforces table-level integrity with the tables in the database.
- A *foreign key (FK)* is used to establish relationships between tables and is a copy of the *PK* of the first table, incorporated into the structure of the second.

2.5 Delphi development platform

It was decided to develop the energy auditing application for use on Microsoft Windows as it is the most commonly used operating systems. Delphi is a primary programming language which provides component-based visual development and a fully visual, two-way Rapid Application Development (RAD) Integrated Development Environment (IDE). Delphi supports native (Win32) development but also provides full support for .Net development. It can produce various Windows applications and is renowned for GUI applications as well as database access. With Delphi, application development is done with pre-built components, drag-and-drop visual design and two-way tools that assist in keeping the visual design and source code synchronised [24].

Delphi can access every major database, including, Oracle, MySQL, DB, Interbase, Firebird and also supports client/server architectures. The *dbExpress* component set was used to access the MySQL database. The most significant features of the *dbExpress* component set are that databases are accessed through unidirectional datasets, which do not buffer data in memory, thus enabling faster query execution. Cursor style navigation is not supported, but can be implemented through the *TDataSetPorivder* and *TClientDataSet* components, providing display and navigational functionality. Delphi-generated applications have a single deployment .exe file and require no additional drivers or special platform-based setup to run on client machines, which simplifies application distribution [24].

Additional features provided by the IDE is intuitive code, integrated local and remote debugging, as well as project management and building. Also included are add-on tools for logging, performance profiling, graphics, charting, reporting, web applications and creating installers. These additional features native to the Delphi IDE increase developing time and enhance the quality of the applications that can be developed [24].

2.6 Unified modelling language

2.6.1 Overview

This project presents the design of a software system. UML has in effect become the standard for visualising, specifying, constructing and documenting software systems. In software engineering, modelling starts with the description of a problem and then moves to the proposition of a solution to solve the problem along with the implementation and deployment. The aim of UML is to reduce the complexity of a system by decomposing it into the basic units of development. UML provides the designers with the ability to design models that not only contain the detailed specifications of software elements, but also high level analysis [27, 28].

2.6.2 UML Diagrams

The various models contained within the UML can be divided into three groups: functional, static and dynamic. The dominant diagram for each of these groups is presented in the remainder of this section together with a short description of each [29].

2.6.2.1 Functional

- *Use-case diagram*: Use case diagrams are used to indicate and provide an overview of the usage requirements for a system and to communicate the scope of the developed project. The diagram consists of one or more use-case diagram and actors. Actors can present a person, organisation, local process or external process that plays a role in one or more of the interactions with the system (actors are indicated by a stick figure), while the use cases describe the set of actions that are of value to the actors [30].

2.6.2.2 Static

- *Class diagram*: The class diagrams depict the detailed design of the object-orientated software and are used to indicate the various classes of the system, their inter-relationships and the operations and attributes associated with each class [30].
- *Component diagram*: The component diagram indicates the dependencies amongst the software components and is used to model the low-level design configuration of a system and to model the technical infrastructure [30].

2.6.2.3 Dynamic

- *State diagram*: The state diagram is used to present the behaviour of a class, actor or subsystem and can present real-time systems. These diagrams depict the behaviour of an entity based on its response to events, showing how the entity reacts to various events based on its current state [30].
- *Communication diagram*: Communication diagrams indicate the message flow between various objects in an object-orientated application and also imply the basic associations between classes [30].

2.6.3 UML diagram used throughout this document

The functionality requirements are indicated by the use-case diagrams; the detailed class design is presented by the class diagram and the dynamic behaviour is presented by activity diagrams. The dominant diagram for both the functional and static groups were used while a specialised form of the state diagram – the activity diagram – was used to present the dynamic behaviour. This state diagram enables one to present the logic contained within a system to the reader.

Equation Chapter (Next) Section 1

3 ENERGY AUDITING METHODOLOGY

3.1 Overview

During the execution of an energy audit, a large amount of data is gathered in order to simulate the energy consumption of a facility. The structure according to which the energy audits were implemented as well as the data required are discussed in the load survey and analysis sections respectively. This chapter concludes with the programming structure used to manage the energy audit and implement the required functionality.

3.2 Load survey

A facility being audited consists of various venues (referred to as areas), each containing numerous electrical loads. Figure 3.1 presents a graphical presentation of a facility, the contained venues and the associated loads. Figure 3.1 also shows the building and load related variables that are discussed in the subsequent section. The multiple areas and loads contained in a facility complicate area and load navigation, as the data set becomes too large. To assist with navigation, the venues and loads were classified based on their associated functionalities, thus divided into area and load classes. These classes, as well as the load types associated with each load class, were determined by conducting a walk-through audit of the E&E department.

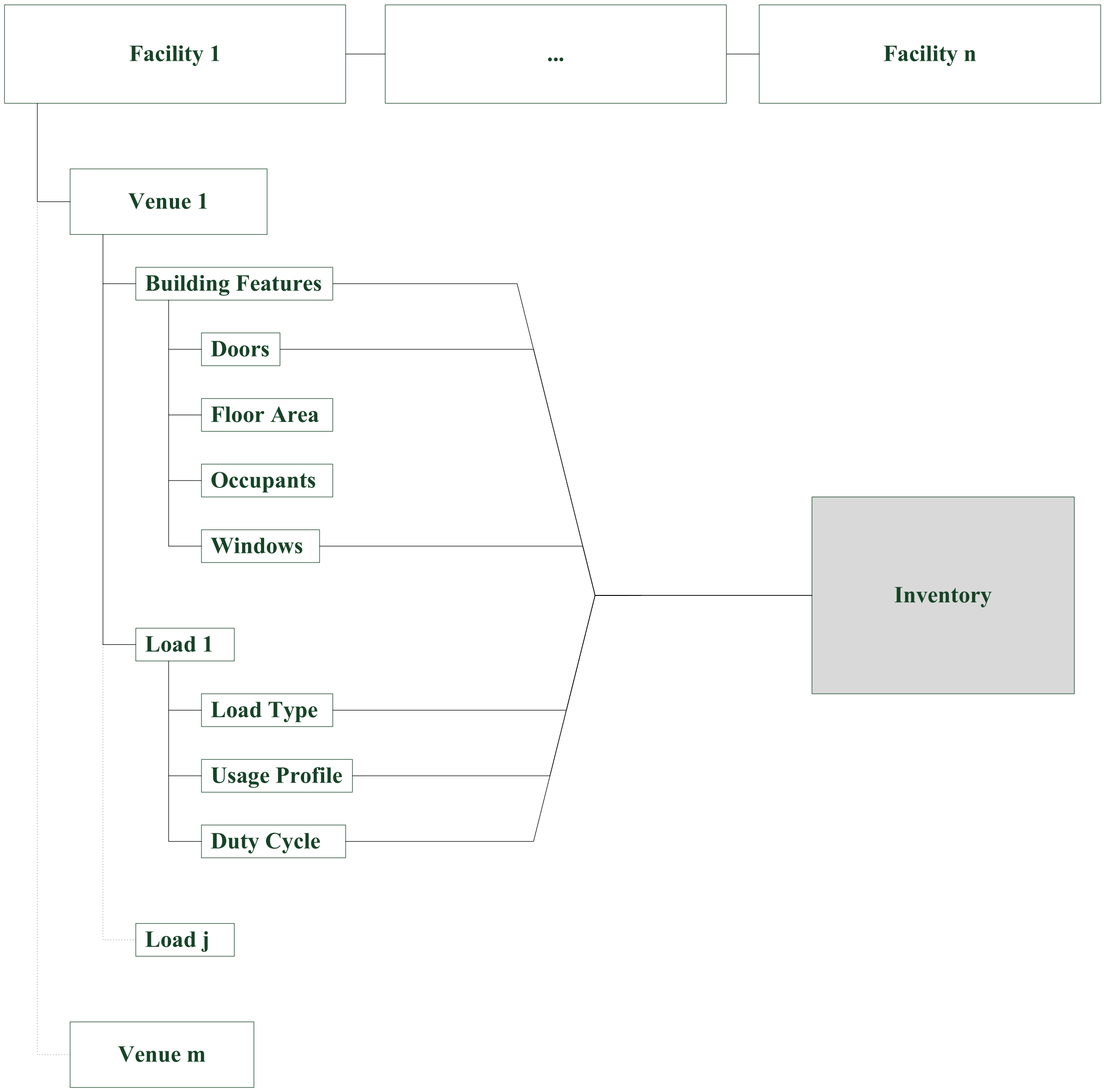

Figure 3.1: The structure according to which the energy audits were implemented.

Table 3.1 contains the area classes, with the load classes and their associated load types presented in Table 3.2.

Table 3.1: Area classes.

Area classes	
Bathroom	Office
Classroom	Laboratory
Passage	Postgraduate office
Foyer	Staff lounge
Workshop	Conference room

Table 3.2: The load classes and their associated load types.

Load classes	Load type
Heating, ventilation and cooling	Air conditioner
IT infrastructure	Computer
	Monitors
Lighting	Lamps
	Luminaires (consists of both lamps and ballasts)

Since each area can contain a significant number of identical loads, each load was assigned with an alpha numeric code, indicating the position within the area. Figure 3.2 shows the alpha numeric codes, which allow for progression in both directions, similar to a chess board or a table.

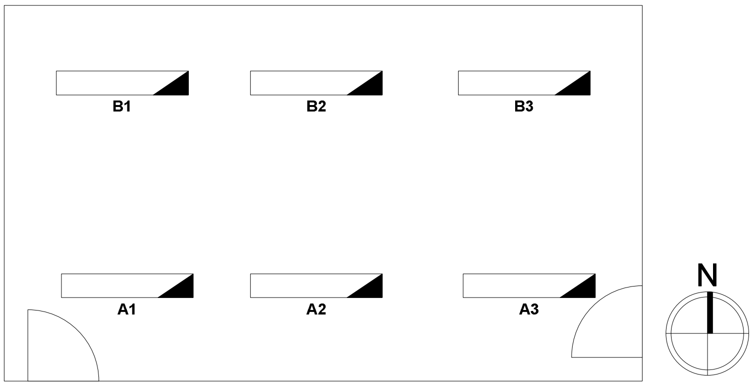

Figure 3.2: An area with 2 doors and electrical loads arranged in 2 rows and 3 columns.

With the insight gained from the walk-through audit and with loads recurring frequently, it was decided to develop a software application to assist with the survey. The survey application consists of a client-side GUI with central database support. The central database keeps all the data, as well as a list of the available loads – referred to as the load inventory. During a survey, loads can be assigned to the various areas and a multi-user environment can be supported without duplicating the original load inventory. Figure 3.1 above illustrates the load assignment from the central load inventory. To manage the user access to the application, three user types were identified:

- *System administrators* have complete access to all the data gathered during all the energy audits and are able to add, delete or alter loads contained in the load inventory.
- *Affiliate administrators* have access to all data gathered for a certain audit and are able to add, delete or alter entries as well as analyse the data gathered.
- *Surveyors* are limited to a specific audit and can only add venues and assign loads.

The client-side application was designed in the Delphi IDE as it supports Win32 development and has a single deployment .exe-file that requires no additional drivers or special platform-based setups to run on client machines. The MySQL-schema was used to implement the database and the client-side data handling was done through the *dbExpress* components.

The data that was to be acquired during the load survey, to enable consumption simulations, is discussed in the subsequent section.

3.3 Analysis

3.3.1 Overview

Irrespective of the functional class, a load is switched *ON* by a user and starts consuming power until the load is switched *OFF*. In order to calculate the power consumed by an electrical load, the following is required:

- *Electrical rating*: This refers to the documented rating contained in the supporting documentation and remains constant when the load is switched *ON*.
- *User's behaviour*: The user's behaviour indicates *when* a load was switched *ON* or *OFF* and is presented by a series of date-and-time stamps indicating when the load switching occurred. In the remainder of the document, a series of date-and-time stamps, with the associated values, will be referred to as a profile. In the case where switching states (*ON*

or *OFF*) are associated with any of these date-and-time stamps, the profile will be referred to as a switching profile.

- *Duty Cycle*: Once a load is operational, it can operate according to a duty cycle. This duty cycle initiates once the load is switched *ON*, periodically repeats and terminates once the load is switched *OFF*. This duty cycle is referred to as the operating duty cycle and is denoted by D_O.

To calculate the energy consumed by an electrical load, one requires the work done (power consumed) over a period of time. Incorporating energy calculations requires continuous switching profiles to be defined for discrete time intervals. The operation duration during a time interval is expressed as a percentage of the interval and is referred to as the active duty cycle (D_A). This altered switching profile is referred to as a usage profile ($\Gamma(n)$) and is required if one wants to calculate the energy consumed by a load.

Simulating the energy consumption of a load for an entire period requires a representative usage profile. Calculating such usage profiles is not always viable, as it is time consuming and does not add significant value to the analysis. In this application, usage profiles were constructed by assigning usage profiles to each day of the period, based on a day classification. The day classifications included in this project are the working week (Monday – Friday), Saturday and Sunday.

The consumption calculation, including the electrical rating, the usage profile and the operational duty cycle, is discussed in the subsequent section, followed by the consumption algorithms implemented for each of the loads.

3.3.2 Consumption calculations

The energy consumed by an electrical load during a certain period of time can be determined by (3.1).

$$E_T = \int_T p(t)dt \tag{3.1}$$

where

E_T denotes the energy consumed during a period,

T denotes the integration interval and

$p(t)$ denotes the power absorbed by the load.

Electrical loads are continuously switched *ON* and *OFF* (1 – *ON* and 0 - *OFF*) by users. This switching characteristic is captured by adding an additional circuit to an already existing data logger, which is presented in Appendix A. Incorporating the switching profile of the load, the power absorbed by the load can be presented as

$$p(t) = Pf(t) \tag{3.2}$$

where

P denotes the electrical rating of a load and

$f(t)$ denotes the switching profile, where:

$$f(t) = f_i \qquad , f_i \in \{0, 1\} \tag{3.3}$$

A switching profile contains the actual time-stamps [yyyy-mm-dd hh:mm] at which an electrical load underwent a state change (the change from *ON – OFF* or *OFF – ON*). These profiles can vary in length and can range from a few hours up to a couple of years, hardware permitting. Figure 3.3 presents a switching profile of an electrical load that consumes $P\,W$ when switched *ON* and $0\,W$ when switched *OFF*. The x-axis in Figure 3.3 presents the time-stamps at which a state-change occurred, with the state of the load indicated on the y-axis.

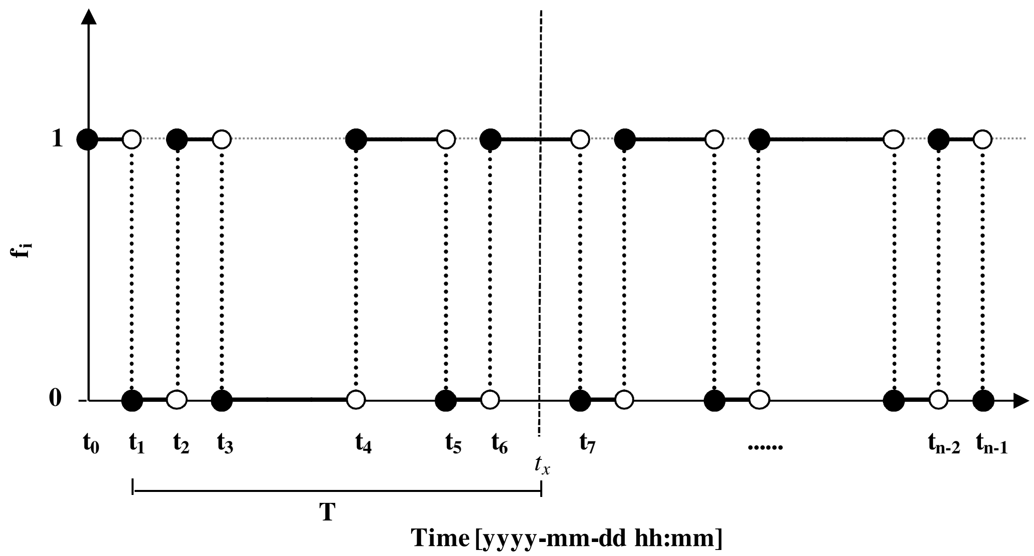

Figure 3.3: A switching profile of an electrical load.

The energy consumed (E_T), during an arbitrainterval T , where

$$T = t \in \mathbb{R} \mid t_1 \le t \le t_x \tag{3.4}$$

can be calculated by (3.5), which simplifies to (3.6).

$$E_T = \begin{cases} Pf_0\left(t_x - t_0\right) & , 0 \le t < t_1 \\ \sum_{i=0}^{j} P\left(f_i(t_{i+1} - t_i)\right) + P\left(f_j(t_x - t_j)\right) & , t_1 \le t < t_n \end{cases} \tag{3.5}$$

$$
\begin{aligned}
E_T &= 0(t_2-t_1)+P(t_3-t_2)+0(t_4-t_3)+P(t_5-t_4)+0(t_6-t_5)+P(t_x-t_6) \\
&= P\big((t_3-t_2)+(t_5-t_4)+(t_x-t_6)\big) \\
&= P\Gamma_T
\end{aligned}
\tag{3.6}
$$

where Γ_T denotes the total time the load was operational during interval T.

Calculating the energy consumed during a single interval does not provide insight into the consumption over a period in time. To obtain this insight, the energy consumption over multiple intervals, representative of a chosen period, is required. With this taken into account, the energy consumption can be calculated as follows:

$$E(n) = P\Gamma(n) \qquad , n \in \mathbb{N} = \{1,2,3...\} \tag{3.7}$$

where $E(n)$ and $\Gamma(n)$ denotes the consumption and usage profiles respectively.

The remainder of this section covers the calculation of a usage profile and the electrical rating.

3.3.2.1 The usage profile

A usage profile describes the user's habit of switching an electrical load *ON* and *OFF*, for a week specification, according to a series of time values determined by a time line. A generic time line is presented in (3.8).

$$T_L = \{t_0, t_1, t_2, t_3 \; ... \; t_{(n-1)}\} \qquad , \textit{where } 00:00 \le t_n \le 23:59 \tag{3.8}$$

The time that a load is operational during a specific time interval t_n, can be expressed as a duty cycle. This duty cycle is referred to as the active duty cycle (D_A) and is calculated by:

$$D_A = \frac{T_{ON}}{t_{n+1}-t_n} \qquad , 0 \le D_A \le 1 \tag{3.9}$$

where

T_{ON} denotes the total operational time during the interval defined by t_n and t_{n+1},

t_n denotes the time value for which the active duty is being calculated, and

t_{n+1} denotes the time value succeeding t_n.

Figure 3.4 presents a switching profile. The time values for which the active duty cycles are to be calculated are t_0, t_1 and t_2. The duration of each interval is denoted by T_0, T_1 and T_2. The operational intervals within the time values are denoted by x_1 and x_2.

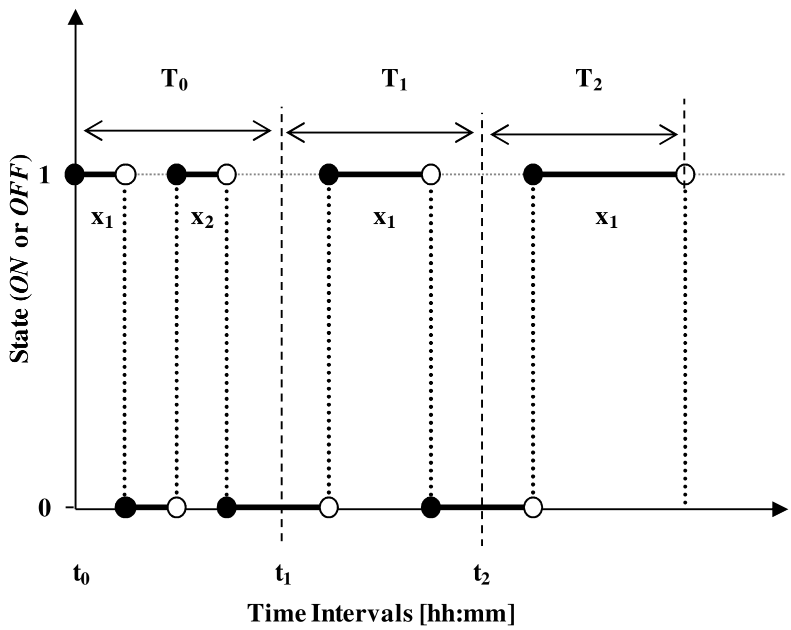

Figure 3.4: Time-line applied to switching profile.

Table 3.3 presents the active duty cycle calculations for each of the time values.

Table 3.3: Active duty cycle calculation for each of the time values.

Time Value	Active Duty Cycle
t_0	$\frac{x_1 + x_2}{T_0}$
t_1	$\frac{x_1}{T_1}$
t_2	$\frac{x_1}{T_2}$

3.3.2.2 The electrical rating

All electrical loads have an electrical rating and are switched *ON* and *OFF* by the user, resulting in the switching profiles from which the usage profile is computed. However, the documented rating does not always present the actual power consumed. Introducing an empirically determined scaling factor enables the actual rating to be determined and is given by:

$$P_{Actual} = \alpha P \tag{3.10}$$

where

P_{Actual} denotes the measured power consumption of the electrical load,

α denotes an empirically determined scaling factor unique to each load, and

P denotes the electrical rating of a load, as specified on the label, name plate or in the supporting documentation.

The α-values calculated for the various loads are presented in Appendix C. Once a load is switched *ON*, it can consume constant power or the consumption can vary depending on the operational duty cycle. A general formula for the calculation of the energy consumption, including the operational duty cycle, is presented in (3.11).

$$E(n) = D_0\left(\Gamma(n)\right) \times P_{Actual} \times \Gamma(n) \qquad , n \in \mathbb{N} = \{1,2,3...\} \tag{3.11}$$

where

$D_0(\Gamma(n))$ denotes the operational duty cycle as a function of the usage profile, for the active duty cycle determines the number of operation duty cycles.

With the operational duty cycle incorporated, there can be distinguished between two load types: loads with an operational duty cycle of 1 and loads with a varying duty cycle. The load types are discussed below.

3.3.2.2.1 Loads with an operational duty cycle of one

Loads for which $D_O = 1$ include ballasts, computers, lamps, luminaires and monitors. The consumption of these loads remains constant during operation, thus simplifying (3.11) to:

$$E(n) = 1 \times P_{Actual} \times \Gamma(n)_{Hour} \qquad [Wh] \tag{3.12}$$

where

$\Gamma(n)_{Hour}$ denotes the active duty cycle expressed as hours.

3.3.2.2.2 Loads with an operational duty cycle of less than one

Certain electrical loads have an operational duty cycle of less than one. Such a duty cycle is implemented through a supplementary control circuit, which ensures that the load switches according to the pre-determined duty cycle or in conjunction with an external variable. The control circuit is switched *ON* when the user switches the load *ON* and the operational duty cycle periodically repeats until the load is switched *OFF*. The implementation of the pre-determined and dependant operational duty cycles is discussed below.

a) Pre-determined operational duty cycle

Figure 3.5 and Figure 3.6 represent an operational duty cycle and an active duty cycle respectively. The period of the operation duty cycle is pre-determined by the manufacturers and the active duty cycle is representative of the user's behaviour. The date-and-time value at which the load is switched *OFF* is represented by t_x and does not have to coincide with the usage profile time-stamps.

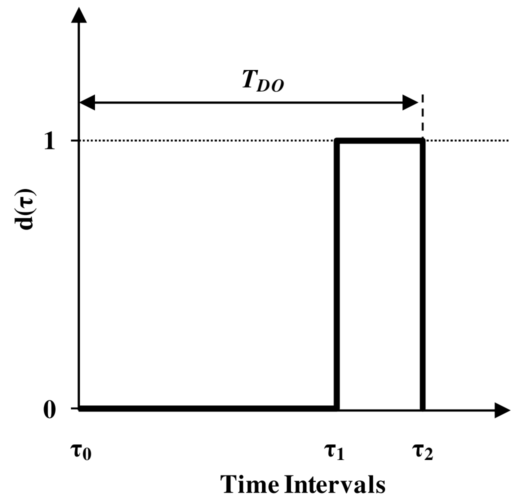

Figure 3.5: D_O

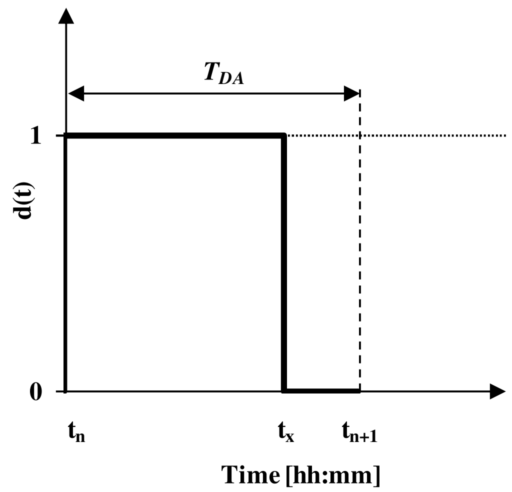

Figure 3.6: D_A

Calculating the actual switching profile of the load from the operation and active duty cycles requires the repetition of the periodic operating duty cycle to occur within the active duty cycle. Applying the operational duty cycle (Figure 3.5) to the active duty cycle (Figure 3.6) results in the actual switching profile of the load during the interval defined by t_n and t_{n+1}. Figure 3.7 presents the switching profile.

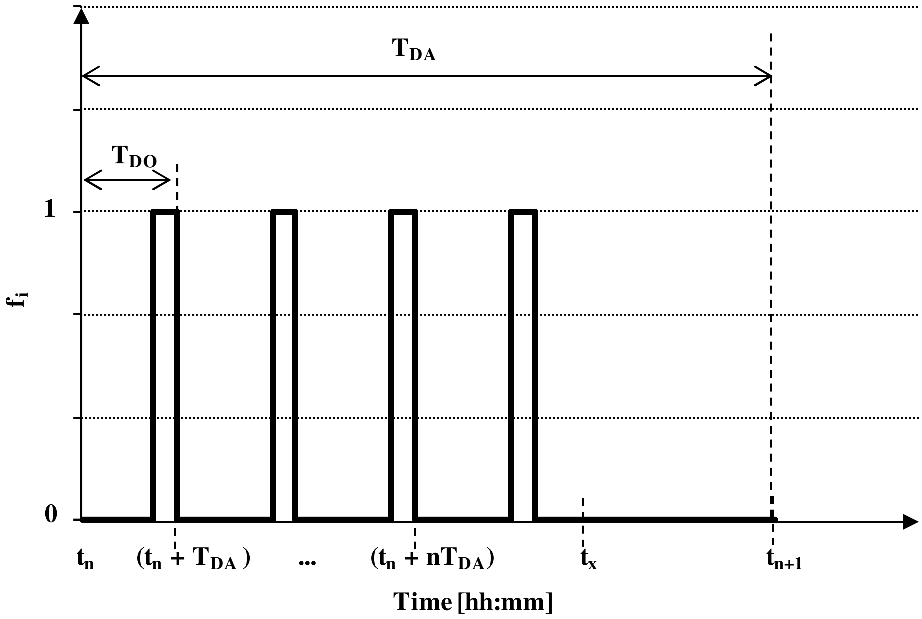

Figure 3.7: Switching profile determined by combining D_O and D_A.

The power consumption associated with the operational duty cycle can be determined by (3.13) and is presented in Figure 3.8.

$$P_{Operational}(\tau) = P_{Actual}d(\tau) + P_{CC}(1 - d(\tau)) \tag{3.13}$$

where

$P_{Operation}(\tau)$ denotes the power consumed during T_{D_O} ,

$d(\tau)$ denotes the operation duty cycle, and

P_{CC} denotes the power consumed by the control circuit.

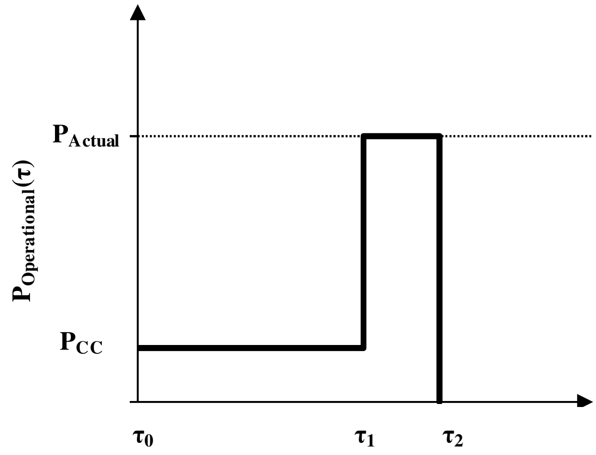

Figure 3.8: $P_{Operational}(\tau)$

When applied to the active duty cycle, the power consumption for t_n can be compiled. Figure 3.9 presents the compiled power consumption

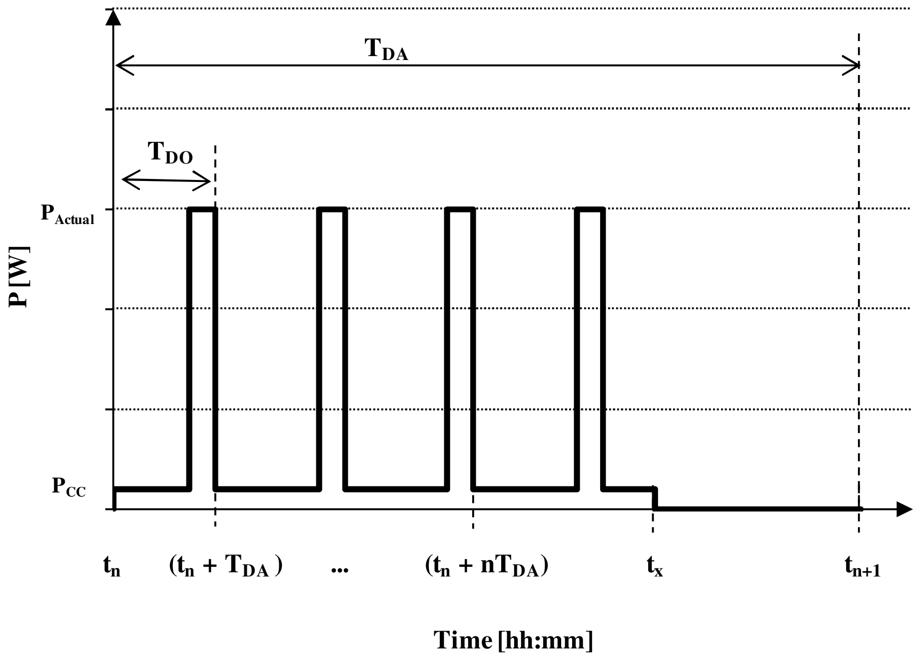

Figure 3.9: Compiled power consumption.

The energy consumed by a load with an estimated power consumption profile as presented in Figure 3.9, can be calculated by (3.14).

$$E(n) = E_{Actual}(n) + E_{CC}(n) \qquad , n \in \mathbb{N} = \{1,2,3...\} \tag{3.14}$$

where

E_{Actual} denotes the actual energy consumed and

E_{CC} denotes the actual energy consumed by the control circuit.

However, with $E_{CC} << E_{Actual}$, (3.14) simplifies to:

$$E(n) = E_{Actual}(n) \qquad , n \in \mathbb{N} = \{1,2,3...\} \tag{3.15}$$

Excluding the power consumption of the control circuit, Figure 3.9 simplifies to Figure 3.10.

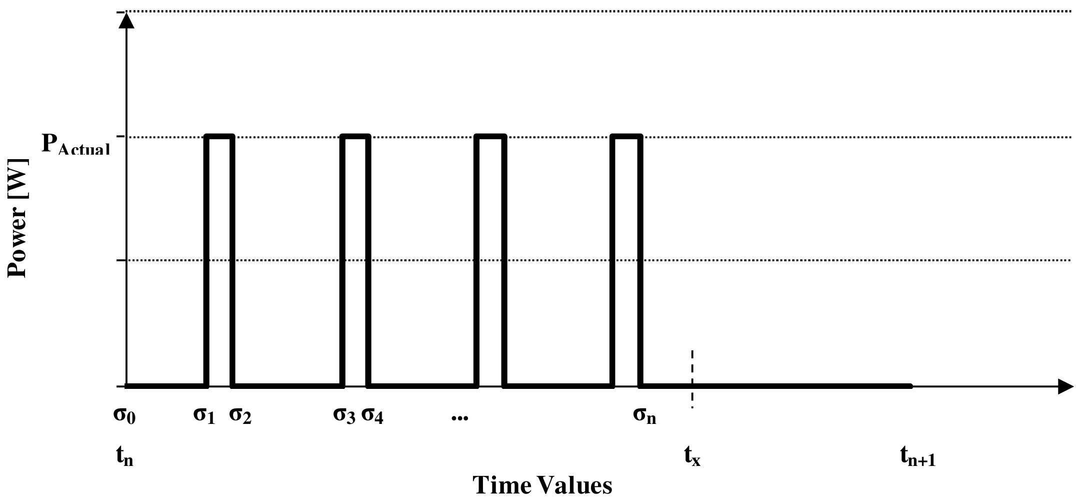

Figure 3.10: Power consumption excluding the control circuit.

The energy consumption, for the interval t_n to t_{n+1}, can then be calculated by (3.16). Note that $(t_n + n\tau_2)$, as presented in Figure 3.9 above, is changed to σ_n in Figure 3.10.

$$E(n) = E_{Actual}(n) = \begin{cases} P_{Actual}(t - t_n) & , t_n \le t < \sigma_1 \\ \sum_{i=0}^{j} P_{Actual}(\sigma_{i+1} - \sigma_i) + P_{Actual}(t - \sigma_j) & , \sigma_1 \le t \le t_x \end{cases} \tag{3.16}$$

The operational duty cycle of air conditioning units, is temperature dependant. The specific algorithm used to determine the operational duty cycle is discussed in the subsequent section.

b) Dependant operational duty cycles

The duty cycle of an air conditioning unit is dynamic and varies in conjunction with the temperature difference between the ambient temperature (T_A) and the thermostat temperature setting (T_T). The operational duty cycle calculations were done with data obtained from the energy audit, knowledge about the characteristics of the air conditioning unit and ambient temperature data. The method implemented was cost effective and took local conditions into account [25].

By combining the documented rating of an air conditioning unit with the heat transfer rate of an area, a sizing ratio can be calculated. The sizing ratio is given by

$$Sizing\ Ratio = \frac{Cooling\ Load}{P} \tag{3.17}$$

where

$Cooling\ Load = C_{Load} \times |\Delta T|$,

P denotes the documented rating of the air conditioning unit,

C_{Load} denotes the cooling per degree difference in temperature, and

$|\Delta T|$ denotes a dimensionless scaling factor that represents the temperature difference between ambient (T_A) and the thermostat setting (T_T) and is given by

$$|\Delta T| = |T_A - T_T| \tag{3.18}$$

Calculating C_{Load} involves the calculation of heat transfer coefficients and rates for the area. Critical in these calculations is the area of the heat transferring surface as well as the materials of which the surface is composed. Figure 3.11 presents a top view of the outer section of a building, with three offices (Office A, Office B and Office C) and an adjacent passage.

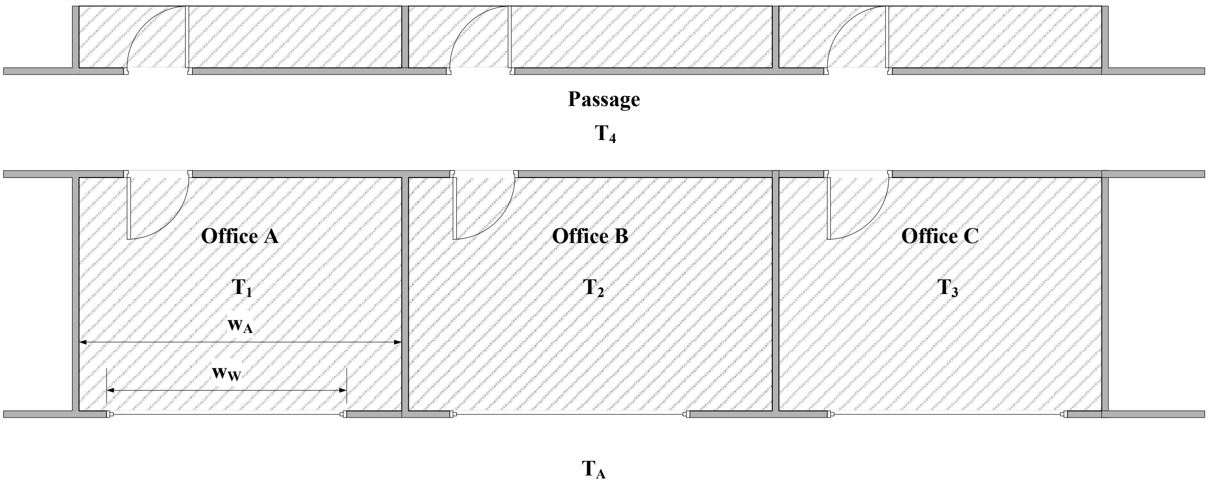

Figure 3.11: Top-view of the outer section of the audited building.

Each of these areas has an associated temperature (T_A, T_{1-3}, T_4) that represents the ambient temperature, the offices' temperature and the passage's temperature respectively. The calculations were simplified by defining the following operational condition:

$$T_1 = T_2 = T_3 = T_4 = T_{Room\ Temperature} \tag{3.19}$$

where

$$T_{Room\ Temperature} = 22.5°C \tag{3.20}$$

By adhering to this operational condition, the only surface area that experiences heat flow is the outer wall. To assist with the calculation of C_{Load}, Table 3.4 was compiled consisting of four columns, each numbered accordingly. To compute C_{Load}, the heat transferring area (of the wall and the window) is required and is placed in column 2. After the area has been determined, a heat transfer coefficient (U-value) is provided for each component and is placed in column 3. If the u-value is known, it can be entered into the table; otherwise the default value will be used.

Multiplying columns 2 and 3 results in the cooling load per degree Celsius – this is placed in column 4. The total cooling load per degree Celsius (C_{Load}) is then determined by adding the individual cooling loads of each of the components. Combining the cooling load per Celsius with $|\Delta T|$ results in the $Cooling\ Load$ for the area [25, 26].

Table 3.4: Calculations for approximate heating and cooling loads.

(1)	(2)	(3)	(4)
Component	**Area (m^2)**	**U-Value**	
Single-pane glass		6.25	
Wall area minus windows and doors		1.7	
C_{Load}			
$\|\Delta T\|$			
$Cooling\ Load$			

For convenience, an incremental duty cycle coefficient is defined as

$$K = \frac{C_{Load}}{P}, \tag{3.21}$$

which simplifies (3.17) to:

$$Sizing\ Ratio = K \times |\Delta T| \tag{3.22}$$

It is assumed that if the cooling load of an area is equal to one, the air conditioning unit will run continuously. Similarly, if the cooling load is equal to $x\%$ of the appliance rating, then it is assumed the appliance will operate $x\%$ of the period. Thus, having the duty cycle coefficient K, D_O can be calculated for some temperature difference, ΔT, by

$$D_O = K \times |\Delta T| \tag{3.23}$$

Equation (3.23) varies as the ambient temperature changes. Keeping the room temperature constant (3.23) can be simplified to

$$D_O(n) = K \times |T_A(n) - 22.5| \tag{3.24}$$

3.3.3 The consumption algorithms for the various loads

3.3.3.1 Overview

The consumption algorithm implemented for each load depends on the operational duty cycle associated with the load. Luminaires, monitors, computers and lamps have an operational duty cycle of one while air conditioning units have a varying operational duty cycle. The consumption algorithms for both these operational duty cycles are discussed in the remainder of this section.

3.3.3.2 $D_O = 1$

The consumption profiles for computers, lamps, luminaires and monitors can be determined by

$$E(n) = 1 \times P_{Actual} \times \Gamma(n)_{hour} \qquad [Wh] \tag{3.25}$$

where

$$P_{Actual} = \alpha P_{NamePlate}$$

with the α-values specified in Appendix B.

When compiling the inventory lists for computers, lamps, luminaires and monitors, the system administrator would have to provide the α-value, the electrical rating and the usage profile so that they can be assigned to the various load entries during the load survey.

3.3.3.3 Varying D_O

The consumption profile of an air conditioning unit can be determined by

$$E(n) = D_O(n) \times P_{Actual} \times \Gamma(n)_{hour} \qquad [Wh] \tag{3.26}$$

where

$$D_O(n) = K \times \left| T_A(n) - 22.5 \right|$$

When compiling the inventory lists for the air conditioning units the system administrator would require the heating and cooling ratings as well as the usage and temperature profiles that can be assigned to the various air conditioning units during the load survey.

3.4 Programming structure

The implementation of the energy auditing structure was done by defining a project that is representative of the facility being audited. With the project defined, the areas can be added, after which the loads are assigned to the various areas. Once the load survey is complete, analyses can be conducted on the gathered data, providing users with insight regarding the consumption of the loads. Additional value is added by enabling users to analyse various scenarios through modifying current load entries and enabling users to simulate the effect on the consumption. Implementing these scenarios requires the alteration of the original data contained in the project, which is achieved by defining a 'case', a duplicate of the original project. A case allows for entry modifications to be made independently of the original project but does not allow additional loads to be added. If loads are to be added, the original project should be updated, after which a new case can be defined.

Managing the defined projects and the associated cases were achieved by defining project owners (affiliates) and a project user/s. Affiliates are the responsible authority conducting the audit where each affiliate can have multiple users consisting of two types: affiliate administrators and surveyors. Affiliate administrators can add projects, grant surveyors access and analyse projects. Surveyors have limited access to projects and can only complete surveys on projects for which they have been granted permission by the affiliate administrators. In addition to these users, there is a system administrator who has access to all the data gathered, can add affiliates and alter data contained in the inventory lists. Figure 3.12 illustrates the implemented structure and the actions that can be conducted on a project. In addition to the structure, the permissions of the affiliate administrators and surveyors are also indicated.

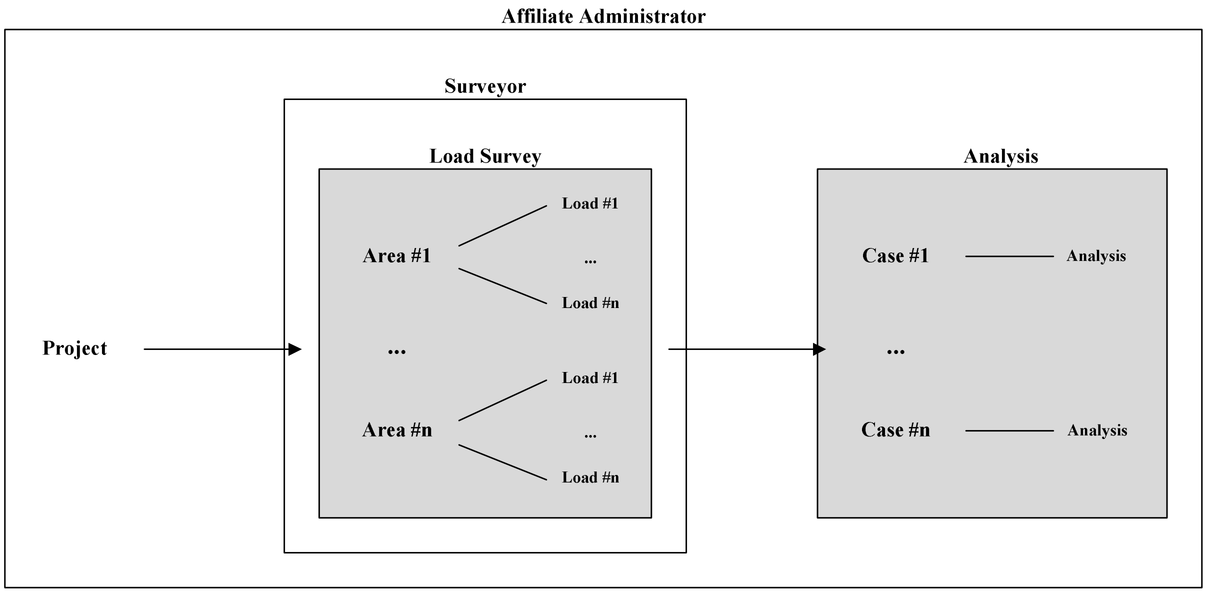

Figure 3.12: The implemented energy auditing structure together with the user permissions.

4 DATABASE DESIGN AND IMPLEMENTATION

4.1 Overview

This chapter presents the tables required to implement the programming structure presented in section 3.4, which was implemented through the *MySQL*-schema. The database tables are comprised of three table types:

- *Main tables*: Containing the information associated with the affiliates, users, projects and load inventory lists.
- *Look-up tables*: Providing the options available for certain fields within the main tables.
- *Linking tables:* Linking individual records contained in two or more main tables.

The first fields of all these tables are titled *ID* and are by default the primary key. Fields ending with *ID*, besides the first field, are *integer* fields and are used as foreign keys. *Designation*, *Description* and *Comments* are three additional fields contained in the main, look-up and linking tables:

- *Designation* refers to the unique name of the record.
- *Description* provides a brief description and the comments field.
- *Comments* contains additional notes.

The *Designation* and *Description* are made public, while *Comments* is kept private; only visible to the system's administrators.

4.2 Administration

The first requirement, before any audit can be completed, is to establish an affiliate as discussed in section 3.4. This table contains affiliate specific information and references the type of affiliate. These requirements were achieved as follows:

- *ContactName*, *Email*, *OfficePhone*, *CellPhone* and *Fax* are the contact details required for each of the affiliates.
- *TypeID* is an *FK*-field referencing the type of affiliate with the available options contained in a look-up table, *AffilateType*.

Figure 4.1 presents the *Affiliate* table, together with the look-up table, *AffiliateType*.

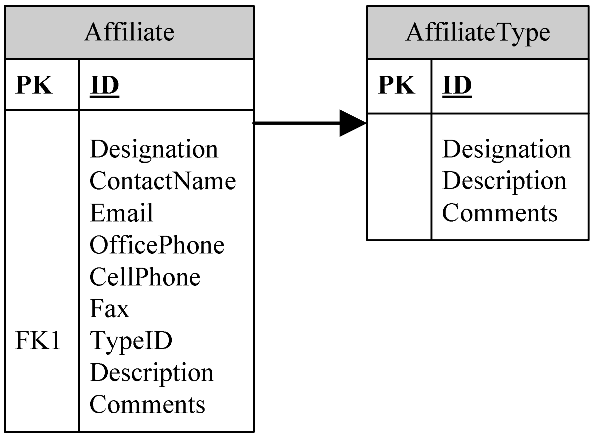

Figure 4.1: The design of the *Affiliate* and *AffiliateType* tables.

The application distinguishes between three user types: system administrator, affiliate administrators and surveyors. System administrators have complete access, while affiliate administrators and surveyors manage users. Each affiliate can have multiple affiliate administrators and surveyors, which can be enabled or disabled depending on the user's status. Access is managed by providing login details for each of the users. This functionality is achieved as follows:

- *AffiliateID* is an *FK* and references *Affiliate*, linking a user and affiliate.
- *TypeID* and *StatusID* are *FK*s used to indicate the type and status of a user and referencing *UserType* and *UserStatus* respectively.
- *Username* and *Password* contain the login details for the various users.

Figure 4.2 presents the *User* table, together with the look-up table, *UserType* and *UserStatus*. Figure 4.2 also includes the *Affiliate* table, representing the relationship between an affiliate and its assigned users.

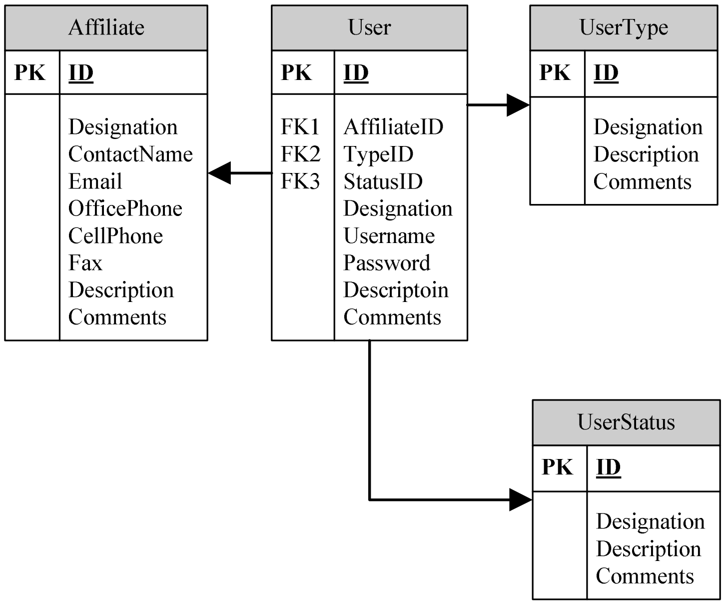

Figure 4.2: Layout of *User* table together with the required look-up tables, *UserType* and *UserStatus,* as well as the *Affiliate* table.

With the users assigned to an affiliate, the projects can be created. An affiliate can have multiple projects, with multiple users having access to a single project. This implementation requires a one-to-many relationship, referred to as 1:*m*. This relationship was implemented by a linking table, *ProjectUser_LinkTable*, consisting of two *FK*-fields (*ProjectID* and *UserID*) that link a user to a project. The nature of this table is such that multiple entries are allowed, providing multiple users with access to a specific project without any structural changes to the *Project* and *User* tables. Figure 4.3 illustrates the relationship between *Affiliate*, *User*, *Project* and *ProjectUser_LinkTable*.

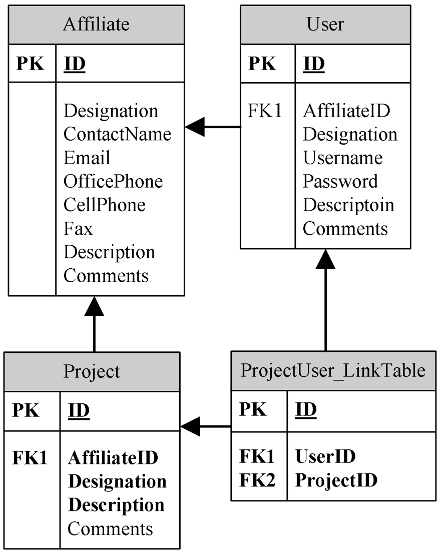

Figure 4.3: *Affiliate*, *Project* and *User* tables together with the linking table *ProjectUser_LinkTable*.

4.3 Load survey

Once the project has been defined and the user created, the load survey can commence. The first step is to add an area; the next is to obtain and provide the responsible authority's details together with the floor area and the associated project. An area classification is incorporated to provide a filtering ability and increasing area selection during the analysis. This was achieved as follows:

- *ClassID* is an *FK* referencing the *AreaClass* table, the table containing the available area classifications.
- *ContactName* and *ContactEmail* respectively contain the responsible authority's name and e-mail address.
- *Occupancy* and *FloorArea* respectively contain the number of occupants and the floor area. These fields are not required by default and are subjected to an area's classification.

Figure 4.4 presents the *Area* and *Project* tables as well as the look-up table, *AreaClass*.

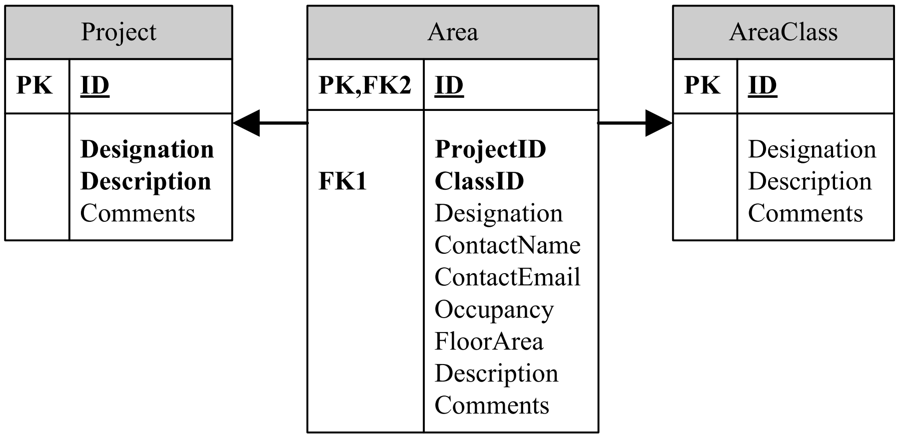

Figure 4.4: ***Area*** **and** ***Project*** **tables together with the look-up table,** ***AreaClass.***

After an area has been added, loads can be assigned. Multiple loads can be assigned to a single area where each load is in turn related to usage profiles, for each of the weekday specifications, an area and a project. This assignment was achieved through the linking table, *LoadEntries*:

- *ProjectID* and *AreaID* are *FK*s used to indicate the project and the area of a load and references *Project* and *Area* tables, respectively.
- *ClassID* and *LoadID* are two *FK*s that respectively reference the *LoadClass* table and a table related to a specific load. These keys are combined to determine the load as the load class presents the table referenced by *LoadID*.
- The usage profiles for each of the weekday specifications were assigned to *WorkingWeekID*, *SaturdayID* and *SundayID*, each referencing *UsageProfile*.

Figure 4.5 presents the design of *LoadEntries* and the referenced tables. However, the table referenced by *LoadID* is not included, for it depends on the load class selected. Note that loads and usage profiles are selected from available options and are assigned to an area. The available options, referred to as the load inventory, are managed by the system's administrator and cannot be altered by affiliate administrators or surveyors. Each table in the load inventory was designed to provide the users with the various options, for both the loads and the usage profiles. The table designs are discussed in the remainder of this section.

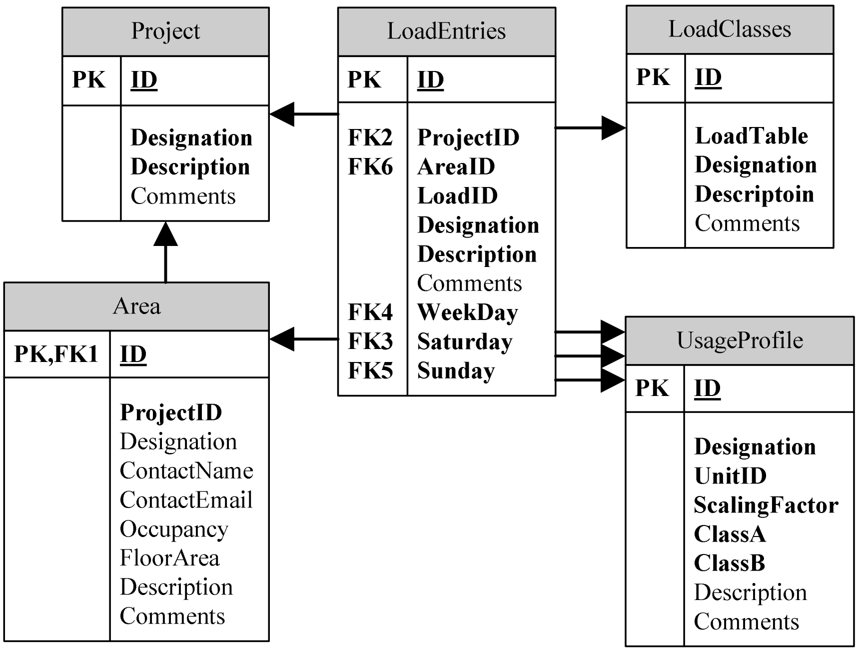

Figure 4.5: The *LoadEntries* table and the associated supplementary tables.

4.3.1 Load inventory table design

In order to enable users to filter the various loads, two load classifications were introduced. The first classification was based on the functionality, referred to as the functional class. The second class filters the loads based on their type and are referred to as the load class. Once a functional class has been selected, the user is presented with the available load classes. Table 4.1 presents the functional classes and their associated load classes.

Table 4.1: The functional classes with their associated load classes.

Functional classes	Load classes
Building features	Windows
Heating, ventilation and cooling	Air conditioners
IT infrastructure	Computers
	Monitors
Lighting	Lamps
	Luminaires

When a load class is selected, the user is presented with a list of the available loads, which is contained in a separate table. The relationship between the load class and the functional class is implemented by a linking table, *FunctionalLoad_LinkTable*, which consists of two *FK*s, *FunctionalClassID* and *LoadClassID,* which respectively reference the *FunctionalClasses* and *LoadClasses* tables. This linking table enables multiple load classes to be assigned to a functional class. The table referenced when a load class is selected, is contained in *LoadTable*, a field of type text in the *LoadClasses* table. Figure 4.6 presents the tables for the functional classes and the load classes, together with the linking table.

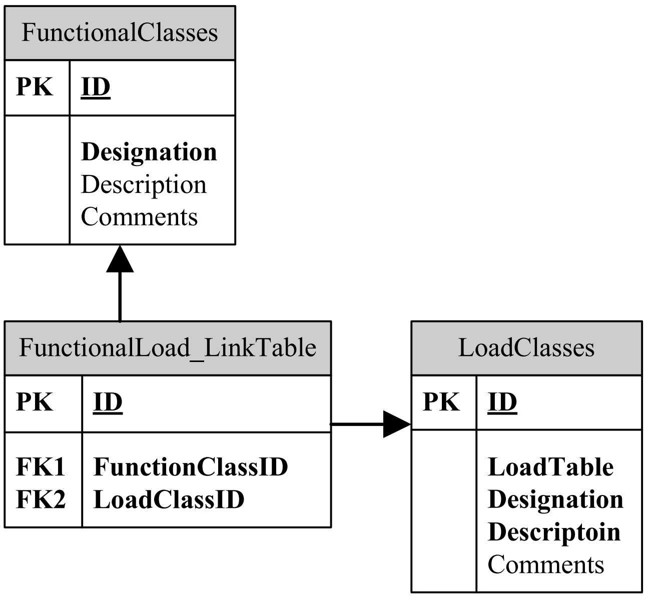

Figure 4.6: *FunctionalClasses* and *LoadClasses* tables with the associated look-up table, *FunctionalLoad_LinkTable*.

Once a load class has been selected, a table is referenced. Figure 4.2 illustrates the tables associated with each of the load classes.

Table 4.2: The load classes and their associated database tables.

Load class	Database table
Windows	*Windows*
Air conditioners	*AirConditioners*
Computer	*Computers*
Monitors	*Monitors*
Lamps	*Lamps*
Luminaires	*Luminaires*

An additional table added to the database, which is not presented in Table 4.2, is *ControlGear*. This table is not included in Table 4.2, as it cannot be assigned to an area but is combined with lamps to compile luminaires. The construction of a luminaire was achieved as follows:

- *LampID* and *BallastID* are *FK*s referencing the *Lamps* and *ControlGear* tables respectively.
- *LampCount* and *BallastCount* are integer fields, referring to the number of lamps and ballasts, respectively included within a luminaire.

Figure 4.7 presents *Luminaires* with its two supplementary tables, *Lamps* and *ControlGear*.

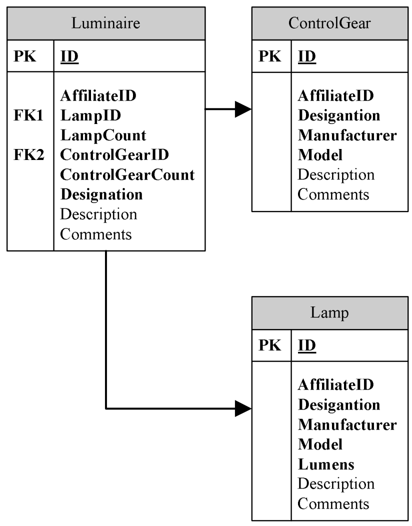

Figure 4.7: *Luminaires* and the associated look-up tables, *ControlGear* and *Lamps*.

The tables: *AirConditioner*, *Computers*, *ControlGear*, *Lamps* and *Monitors*, contain load related information such as the manufacturer, the model, the duty cycle and the type of load. These requirements are achieved as follows:

- *TypeID* and *CycleID* are *FKs* referencing two look-up tables containing the various types and the available operational duty cycles, respectively. The operational duty cycle is a profile and the design will be discussed in the subsequent section.

- The *Manufacturer* and *Model* fields refer to the manufacturer and the model of each load respectively.

In addition to the fields mentioned, *Lamp* contains an additional field, *Lumens*, containing the light intensity associated with a lamp. Figure 4.8 presents *AirConditioner*, *Computer*, *ControlGear*, *Lamp*, *Monitor* and *Luminaires*, together with their associated look-up tables containing the various types of loads.

The *Window* differs from the previous tables and contains fields referring to the physical aspects of the windows. *Height* and *Width* are decimal fields containing the physical dimensions of the window. *CoverID* is an *FK* referencing the *WindowCover* table, containing the available cover options. Figure 4.9 presents *Window* and its associated look-up table.

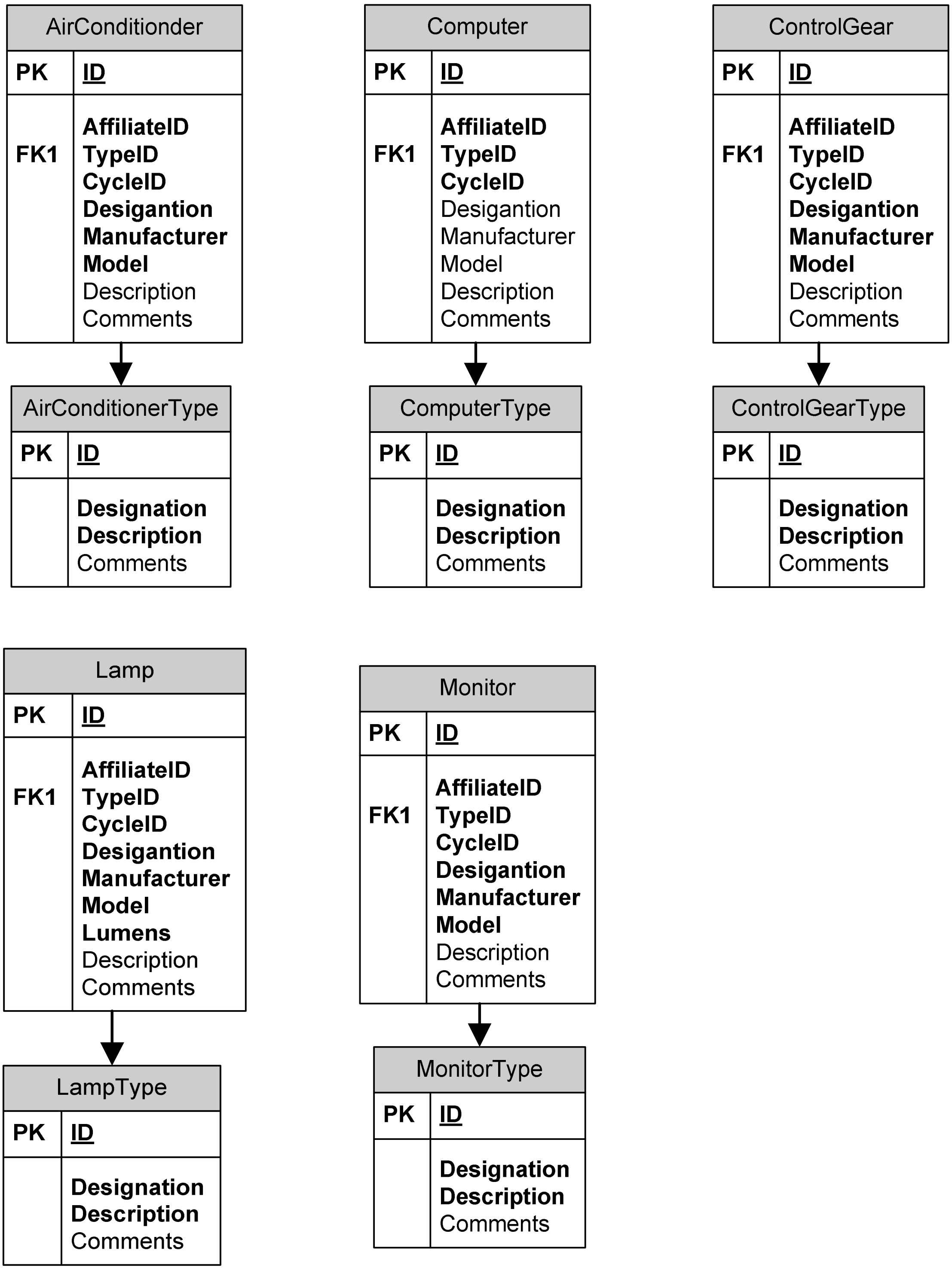

Figure 4.8: The tables required for load inventory.

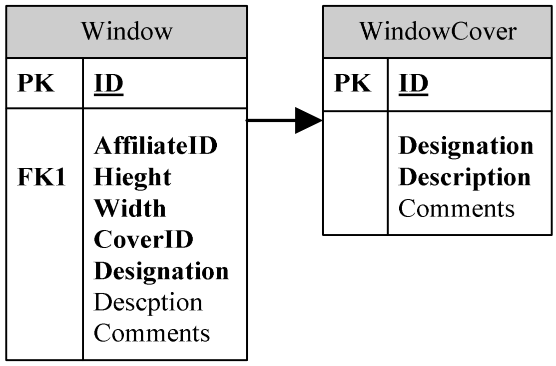

Figure 4.9: The *Window* table and the lookup table, *WindowCover*.

4.3.2 Usage profiles

A usage profile is a profile type in which the values associated with each date-and-time stamp presents the active duty cycle. To implement a profile in a database, two tables are required: *Profile* and *ProfileDateAndTime*. The *Profile* table contains additional information related to the profile such as the unit and the scaling factor, and allows for three additional *FK*s that can reference any table depending on the required functionality. These requirements are met as follows:

- *UnitID* is an *FK* and references the *Unit* table which constrains the available units that can be assigned to an analysis.
- *Scalingfactor* is a decimal value, enabling the data values to be scaled if required.
- *ClassA*, *ClassB* and *ClassC* are *FK*s referencing look-up tables that can vary depending on the type of profile.

The date-and-time stamps and the associated values of the profile are contained in *ProfileDateAndTime* and must be related to the additional information contained in *Profile*. These requirements are achieved as follows:

- *ProfileID* is an *FK* that references the *Profile* table.
- *DateTime* is a date-time field, containing the date-and-time stamps of the profile.

- *Value* is a field of type double, containing the value associated with the date-time value.

Figure 4.10 illustrates the generic *Profile* and *ProfileDateAndTime* tables required to implement a profile.

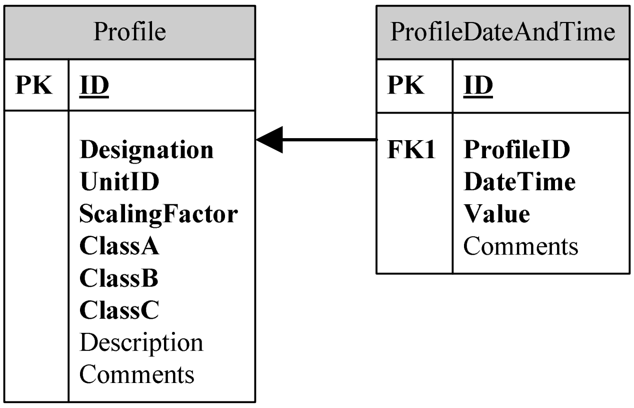

Figure 4.10: The *Profile* and *ProfileDateAndTime* tables.

The project makes use of three different profiles which are presented in Table 4.3, together with the tables referenced by the three *FK*s – *ClassA*, *ClassB* and *ClassC*.

Table 4.3: The various profiles used throughout this project.

Profile	Foreign key (FK)	Referenced table	Functionality
Usage profile	Class A	*LoadClass*	Associates the usage profiles with a certain load class
	Class B	*WeekDay*	Associates the usage profile with a certain day of the week.
	Class C	-	Provisional field for future use.
Duty cycle	Class A	*LoadClasses*	Associates a cycle profile to a certain load class.
	Class B	-	Provisional field for future use.
	Class C	-	Provisional field for future use.
Analysis	Class A	*Project*	Linking a certain analysis and project.
	Class B	*AnalysisType*	Identifies the type of analysis.
	Class C	-	Provisional filed for future use

4.4 Analysis

When a project (complete or incomplete) is to be analysed, the original project's entries are to be duplicated within the *LoadEntries* table and a new project, referred to as a 'case', is to be created. The duplicated entries in *LoadEntries* should then reference the *ID* of the newly created 'case' to enable scenario analysis to be conducted. Projects and cases are related through a linking table that enables the association of the various cases with projects. This association is implemented with two *FK*s, *ProjectID* and *CaseID*, which both reference the *Project* table but with a distinction made in the project's type. Figure 4.11 presents the linking table.

ProjectCase_LinkTable	
PK	**ID**
	ProjectID **CaseID**

Figure 4.11: Project-case linking table.

The result gained from the analysis is written into the *Analysis* table*,* a profile*,* which is implemented as discussed in section 4.3.2. The additional information required for the analysis is contained in *AnalysisAdditionalInformation* which is presented in Figure 4.12 and contains the following fields:

- *ProjectID* references *Project*, linking additional analysis information to a specific project (case).
- *TemperatureID,* which references the temperature profiles within *UsageProfile.*
- *RoomTemperature* and *DayTemperature*, fields of type double, containing the average (avg.) room temperature [°C] and avg. ambient temperature, respectively.
- *UValue_Wall* and *UValue_Glass*: Fields of type double that contain the u-values associated with the walls and the glass respectively.
- *DateTimeFrom* and *DateTimeTo*: Date-time fields indicating the period over which the analysis was conducted.

AnalysisAdditionalInformation	
PK	**<u>ID</u>**
	RoomTemperature **DayTemperature** **UValue_Wall** **UValue_Glass** **DateTimeFrom** **DateTimeTo**

Figure 4.12: ***AnalysisAdditionalInformation.***

The complete database design is contained in Appendix D.

5 CLIENT-SIDE APPLICATION DESIGN AND IMPLEMENTATION

5.1 Overview

Chapter 5 presents the use-case diagrams of the various client-side forms, the scope as well as an overview of the usage requirements. The client-side application was designed based on the programming structure presented in section 3.4 and enables users to access the tables in Chapter 4. In addition to the three sections presented section 3.4, two additional sections, Login and Home, were included. These sections assist with access control and enable easy and efficient navigation between the various sections identified in section 3.4. Figure 5.1 presents the various sections and indicates the flow existing them.

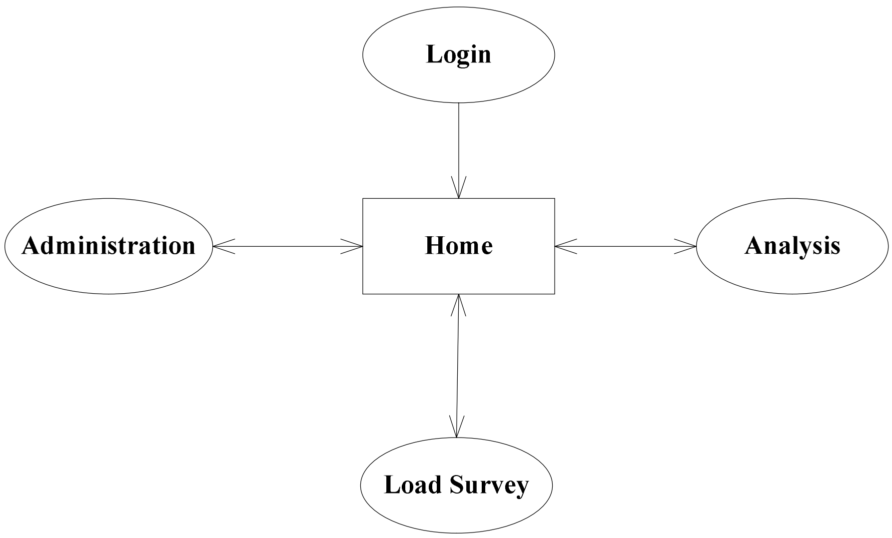

Figure 5.1: The sections according to which the application was designed.

Login provides users with access to the main form, *Home*. From the *Home* form users can navigate to the various sections, depending on their assigned permissions. The remainder of this chapter provides the use-case diagrams and the tables referenced for each of the sections presented in Figure 5.1. Table 5.1 contains a description of each section.

Table 5.1: The application sections together with a short description of each.

Section	Description
Login	User authentication
Home	Main navigation
Administration	The administration related components required for management.
Analysis	The analysis components consisting of the analysis algorithm, supplementary information as well as the results obtained from the various analyses.
Load survey	The components related to the load survey.

5.2 Login

Login accesses the *User* table and prompts the user for a username and password. The username is used to retrieve the password, which is then compared to the one provided by the user. If the password provided by the user and the one retrieved from the *User* table are a match, the user's permissions are set and presented with the *Home* form. Figure 5.2 presents the use-case diagram.

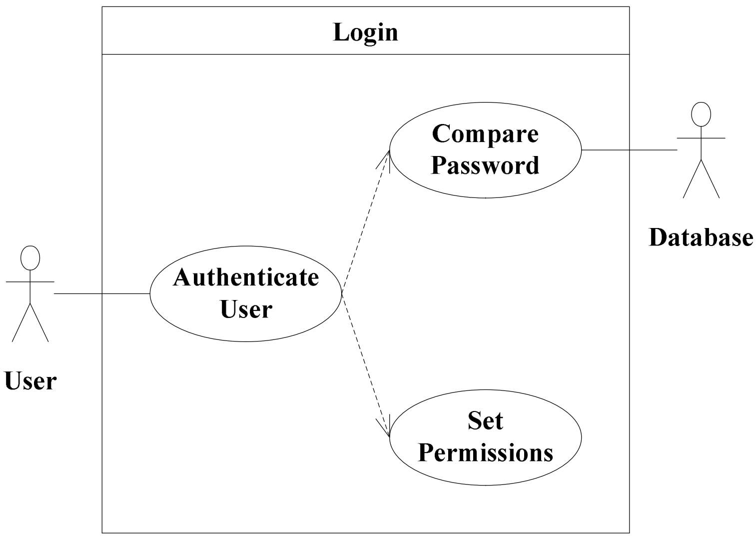

Figure 5.2: The use-case diagram for the *Login* form.

5.3 Home

Home provides the users with navigational options, determined by the user's type and does not directly access any tables. System administrators can access the administration section where they can manage affiliates, users and projects. In addition to their administration capabilities, system administrators can also access the load inventory, where they can manage loads, duty cycles and usage profiles. Affiliate administrators have limited administrative privileges and can only manage their own projects. They can also grant surveyors permission to certain projects. Besides administrative privileges, affiliate administrators can conduct analyses on and complete load surveys for their projects. Surveyors have the least access of all the users and can only complete load surveys on projects to which they have been granted permission. Figure 5.3 presents the use-case diagram.

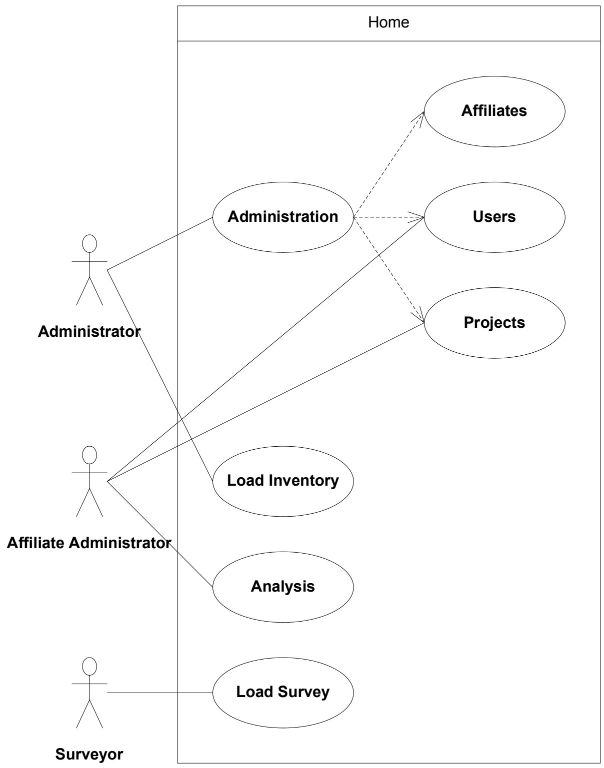

Figure 5.3: Use-case diagram indicating the sections to which the various user types have access.

5.4 Administration

The administration section provides system administrators with access to the *Affiliate*, *Project* and *User* tables and allows them to add, delete or alter entries. A generic form, providing the required functionality, was designed. Figure 5.4 presents the use-case diagram.

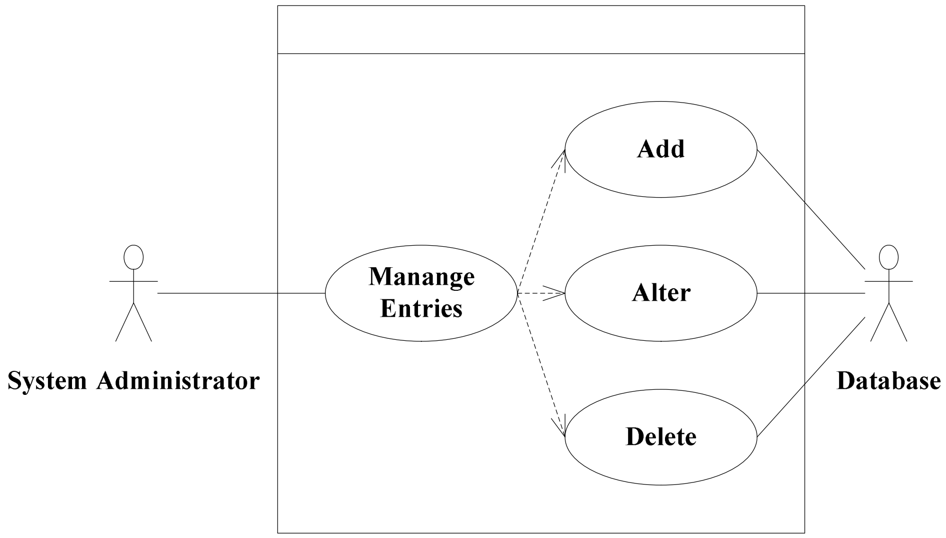

Figure 5.4: The generic use-case diagram for the administration section.

5.5 Load survey

The load survey section consists of two sections: the load inventory and usage profile and the load survey. These sections are discussed in the remainder of the section.

5.5.1 Load inventory and usage profile

5.5.1.1 Load inventory

The load inventory allows system administrators to add, delete and alter the options available for each of the loads by providing access to the various load tables. The form used implements the exact same functionality as the administration form presented in Figure 5.4.

5.5.1.2 Usage profile

Calculating the active duty cycle for all the time values contained in a usage profile, requires the user to upload a switching profile as a CSV-file. Once the files have been uploaded, additional parameters relating to the load type and the weekday specification are set. With the user inputs provided, the application (system) determines the active duty cycle for each time value contained in the usage profile as presented in section 3.3.2.1. After the active duty cycles have been calculated, the complete usage profile is saved to the

UsageProfileInformation and *UsageProfileData* tables in the database. Figure 5.5 presents the use-case diagram.

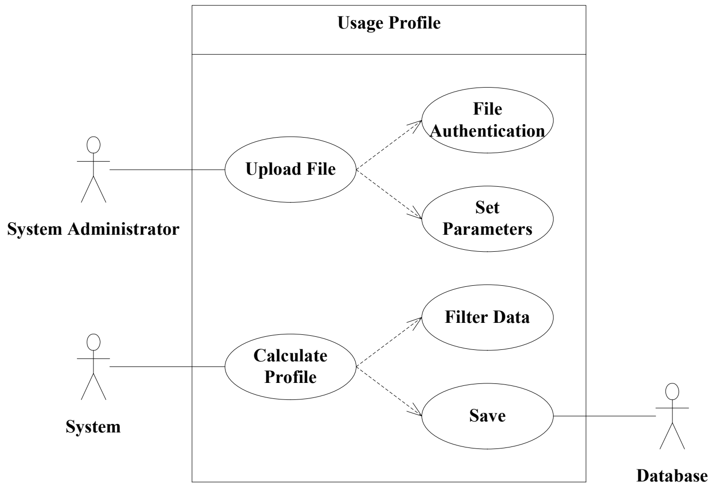

Figure 5.5: Use-case diagram for the implementation of the usage profile calculation algorithm.

Figure 5.6 presents the working week usage-profile, as calculated from the switching profile presented in Figure A-7. The time values are presented on the x-axis, with the operational duty cycle indicated on the y-axis. The usage profiles determined for each load is presented in Appendix B.

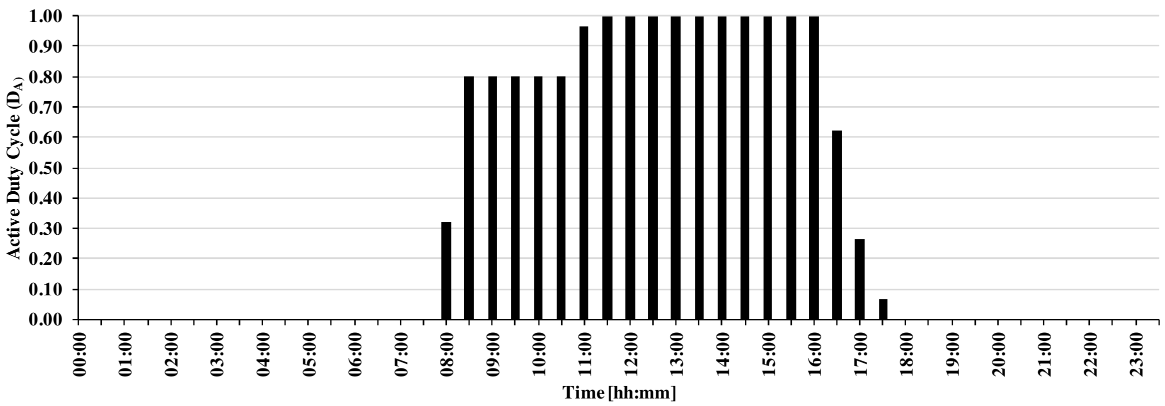

Figure 5.6: The usage profile representative of a typical working-week day, obtained from the switching profile presented in Figure A-7.

5.5.2 Load survey

The load survey allows affiliate administrators to access the *Area* table and add, alter or delete areas of a project. With an area selected, affiliate administrators and surveyors can access the *LoadEntries* table and add loads from the load inventory. The referenced load table is determined by the functional class and the load class selected. Figure 5.7 presents the use-case diagram.

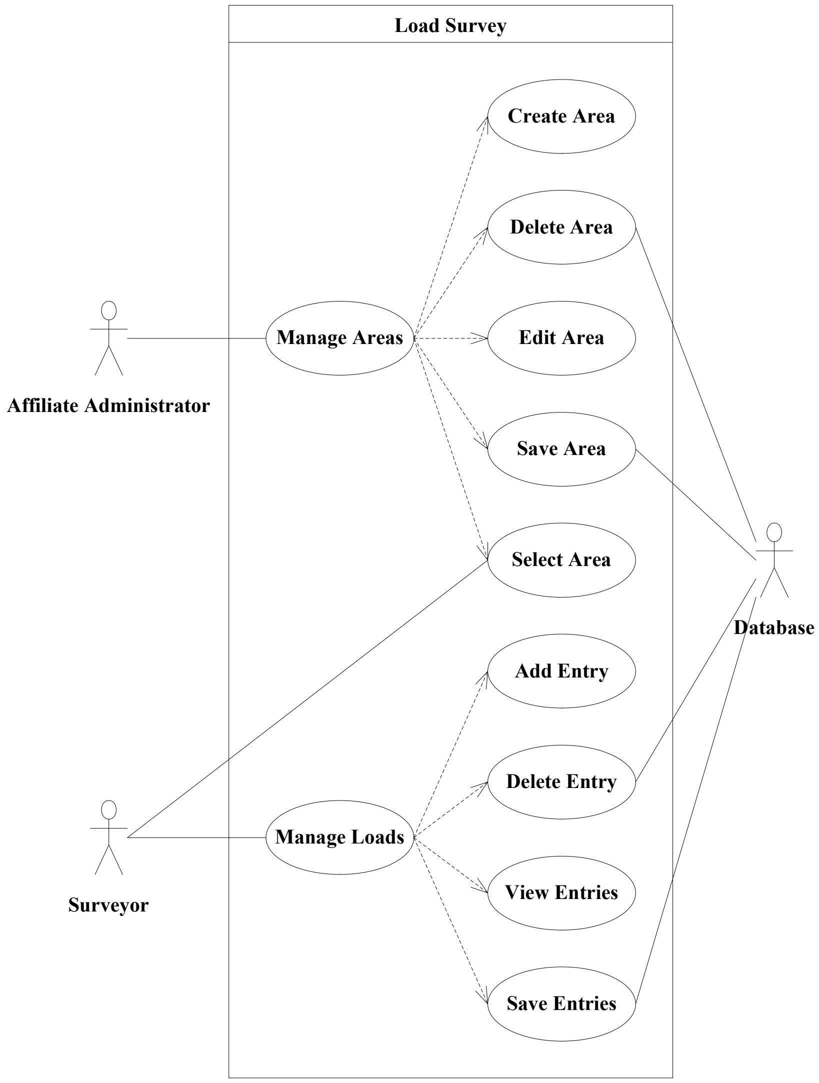

Figure 5.7: Use-case diagram of the implementation of the load survey.

5.6 Analysis

The analysis form allows affiliate administrators to access the *Project*, *LoadEntries* and analysis table. Figure 5.8 presents the use-case diagram. Users are able to create cases of existing projects, alter entries and analyse created cases. Before a simulation can be completed, the user is required to select which entries are to be included in the simulation and must provide additional variables such as the temperature profile, the u-values and the period for which the simulations are to be conducted.

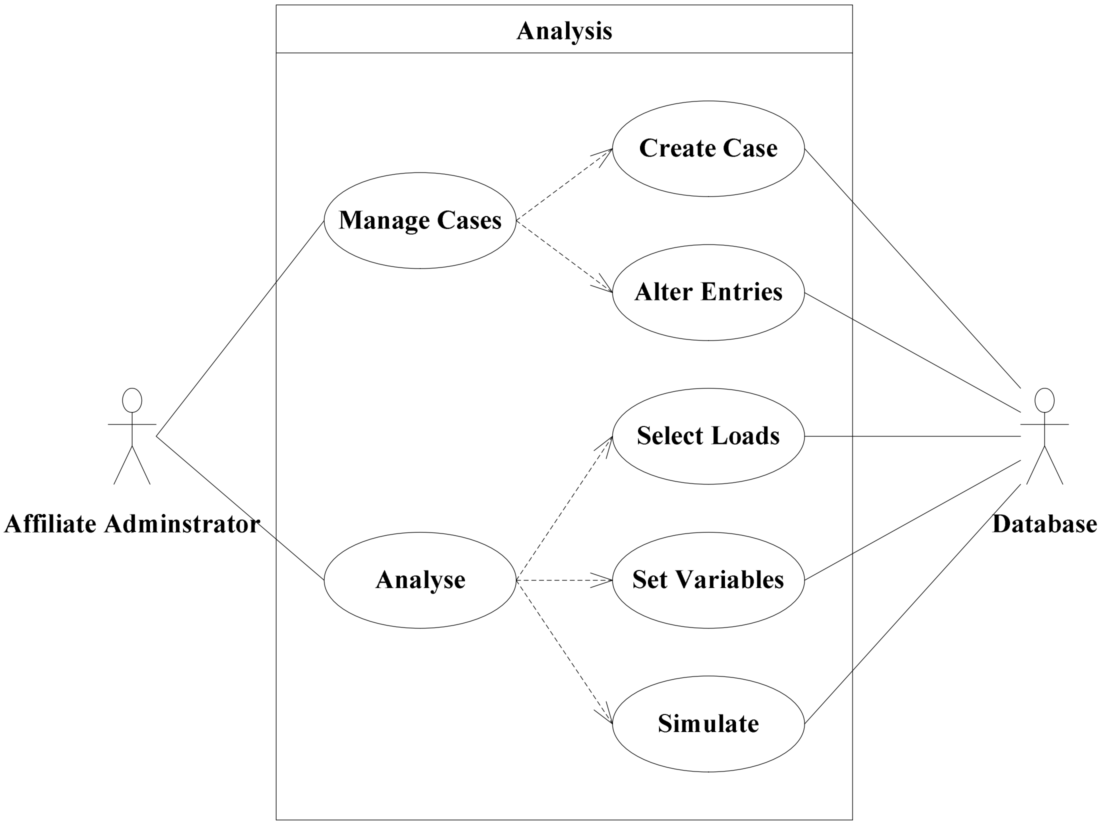

Figure 5.8: Use-case diagram of the implementation of the analysis.

After the simulation is completed, the user can save or discard the result. Once a result is saved, independently of the case, the results can only be viewed and not altered. Altering the results requires a new analysis to be conducted on the case containing the required changes.

6 CASE STUDY AND RESULTS

6.1 Overview

Chapter 6 presents the programme validation and a case study. The programme validation confirms the implementation of the usage profile algorithm and simulates the consumption for each load included in this application. The case study compares actual consumption data to the simulated consumption to determine the accuracy of the application.

6.2 Programme validation

6.2.1 Overview

This section presents the validation of the implementation of the usage profile algorithm, as presented in section 3.3.2.1, followed by the validation of the consumption algorithm implementation for each of the loads, as discussed in section 3.3.3.

6.2.2 Usage Profile

The calculation of usage profiles, representative of the week specifications: working week (Mon. – Fri.), Saturday and Sunday, requires the calculation of a usage profile for each of the days contained in the switching profile. Once the usage profiles have been calculated, they are summed and averaged to determine a single usage profile representative of each of the week specifications.

This section presents the validation of the implementation of the usage profile algorithm as well as the averaging of the usage profiles to determine a single usage profile, representative of the week day specifications.

6.2.2.1 Implementation of the usage profile algorithm

To validate the implementation of the usage profile algorithm, a custom switching prolife for a day was compiled. The averaging effect could be excluded and the usage profile could directly be calculated from the switching profile, as the switching profile only represents a day. The switching profile is presented by rows one and two of Table 6.1, with the hourly time values presented in the first row and the time that the load was operational during each hour, in the second row. Note that for illustration purposes, the load is operational from the start of every hour and remains operational for the duration, presented in the second row.

Table 6.1: A custom switching profile used to validate the usage profile implementation.

1	Time [hh:mm]	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00		08:00		09:00		10:00		11:00		12:00	
2	ON-Time [minutes]	0	5	10	15	20	25	30	35		40		45		50		55		55	
3	Usage-profile Time Values [hh:mm]	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30
4	Calculated D_A	0	0.17	0.33	0.5	0.67	0.83	1	1	17	1	0.33	1	0.5	1	0.67	1	0.83	1	0.83

1	Time [hh:mm]	13:00		14:00		15:00		16:00		17:00	18:00	19:00	20:00	21:00	22:00	23:00
2	ON-Time [minutes]	50		45		40		35		30	25	20	15	10	5	0
3	Usage-profile Time Values [hh:mm]	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	18:00	19:00	20:00	21:00	22:00	23:00
4	Calculated D_A	1	0.67	1	0.5	1	0.33	1	0.17	1	0.83	0.67	0.5	0.33	0.17	0

Figure 6.1 presents the usage profile, as calculated from the switching profile in Table 6.1 above. In order to validate the values, the active duty cycles were manually calculated for each of the time values contained in the usage profile. The time values of the usage profile are presented in the third row of Table 6.1, with the active duty cycle, calculated for each time value presented in the fourth row.

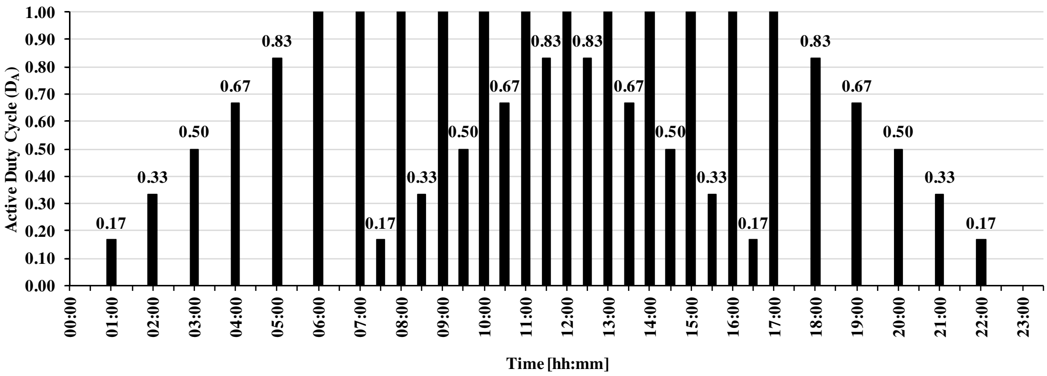

Figure 6.1: The usage profile calculated from the switching profile presented in Table 6.1.

6.2.2.2 Averaging of usage profiles

To validate the summing and averaging of usage profiles to determine an average profile representative of a week specification, a custom switching profile that represents a week was compiled. The switching profile is presented in Table 6.2 and indicates the period, for each day of the week, during which the load is operational. The load is operational from 00:00 to 08:00 and then again from 17:00 to 00:00 on Mondays. From Tuesday to Thursday the load is operational from 08:00 to 17:00. On Fridays, the load operates from 08:00 to 13:00. It is switched *OFF* from 13:00 to 14:00 and operates again from 14:00 to 17:00.

Table 6.2: Custom switching profile

	Monday		Tuesday - Thursday	Friday	
ON-Time [hh:mm]	00:00 – 08:00	17:00 – 00:00	08:00 - 17:00	08:00 – 13:00	14:00 - 17:00

Figure 6.2 presents the usage profile calculated from the switching profile in Table 6.2. In order to validate the values, the active duty cycles were manually calculated for each of the periods contained in the usage profile. Table 6.3 presents the calculated active duty cycles for each of the periods.

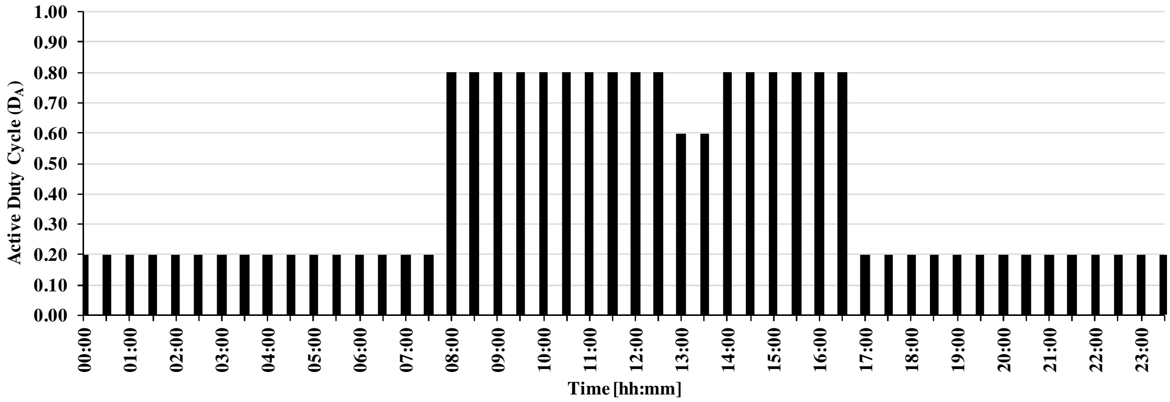

Figure 6.2: The usage profile calculated from the switching profile presented in Table 6.2.

Table 6.3: Calculated D_A values.

	00:00 – 08:00	08:00 – 13:00	13:00 – 14:00	14:00 – 17:00	17:00 – 00:00
Active Duty Cycle (D_A)	0.2	0.8	0.6	0.8	0.2

6.2.3 Consumption simulation per load

Validation of the retrieval and implementation of the database variables was done by simulating the consumption for each load and then comparing the simulated and calculated results. This section presents the simulated consumption for each load, calculated according to the functional classes. The calculated consumption values, to which the simulated results were compared, are presented in Appendix F.

6.2.3.1 Heating, ventilation and cooling

The consumption of an air conditioning unit is dynamic and varies as the temperature difference between the ambient temperature (T_A) and the thermostat temperature setting (T_T) varies. The variables of the air conditioning unit and the specifications of the area used to validate the consumption are presented in Table 6.4.

Table 6.4: The variables of the air conditioning unit and the specifications of the area used.

Rating (P) [W]	T_T [°C]	Wall		Window		C_{Load}	K	Usage Profile
		Area [m^2]	u-value	Area [m^2]	u-value			
2150	22.5	11.22	1.7	6.25	6.25	49.195	0.023	Figure C-8

The air conditioning unit has a documented rating (P) of 2150 W. The assigned usage profile for the working week is presented in Figure C-8 in Appendix C. No usage profile for Saturday and Sunday was recorded. The thermostat setting (T_T) was taken as $22.5\ °C$; the half-hourly ambient temperature profile used is presented in Figure 6.3.

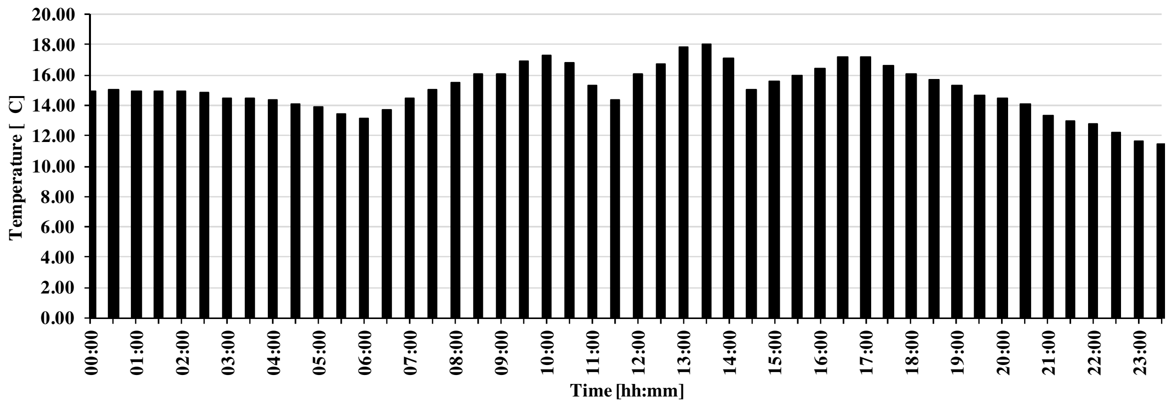

Figure 6.3: Temperature profile for a day in a working week.

The outer wall for the area used to simulate the air conditioners consumption is 11.22 m^2 and the material has a u-value of 1.7. The window included in the area has an area of 6.25 m^2 and the u-value of the glass was taken as 6.25. From the area variables, C_{Load} and K were calculated as 49.195 and 0.023 respectively. Figure 6.4 presents the simulated consumption for the working week. The calculated consumption values are presented in Figure F-1 (Appendix F).

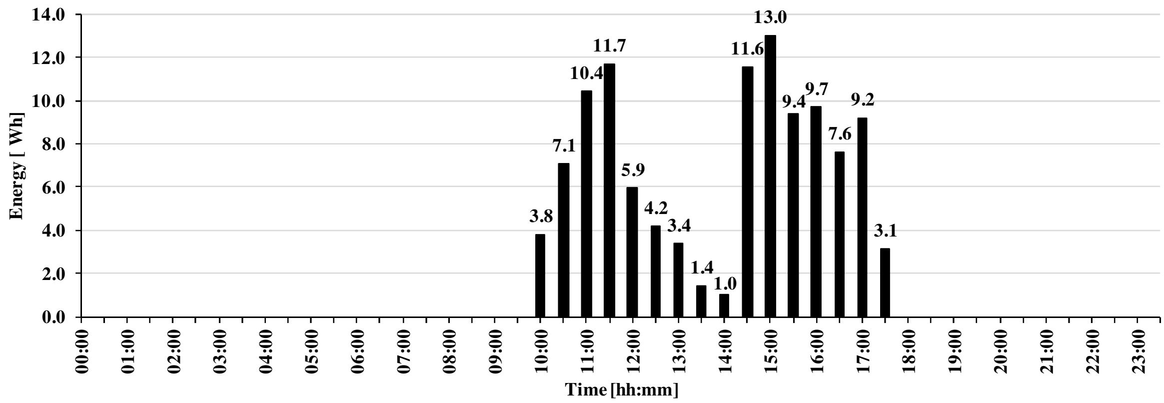

Figure 6.4: The air conditioning unit's simulated consumption profile for the working week usage profile.

6.2.3.2 IT infrastructure

The IT infrastructure functional class presents the simulated consumptions for the computers and the monitors. It was only necessary to simulate one computer and monitor, as it is the data retrieval from the database that was to be verified, and not the actual consumption profiles for the various loads.

6.2.3.2.1 Computers

The variables of the simulated computer are presented in Table 6.5. The computer has a documented rating of 400 W and a calculated α-value of 24.5 %. The assigned usage profiles for the working week, Saturday and Sunday are presented in Figure C-9, Figure C-10 and Figure C-11 respectively. The simulated consumption for the working week, Saturday and Sunday are presented in Figure 6.5, Figure 6.6 and Figure 6.7 respectively. The calculated values are presented in Figure F-2.

Table 6.5: Variables of the simulated computer.

Rating (P) [W]	α-value [%]	Usage profile	
400.0	24.5	Mon. – Fri.	Figure C-9
		Sat.	Figure C-10
		Sun.	Figure C-11

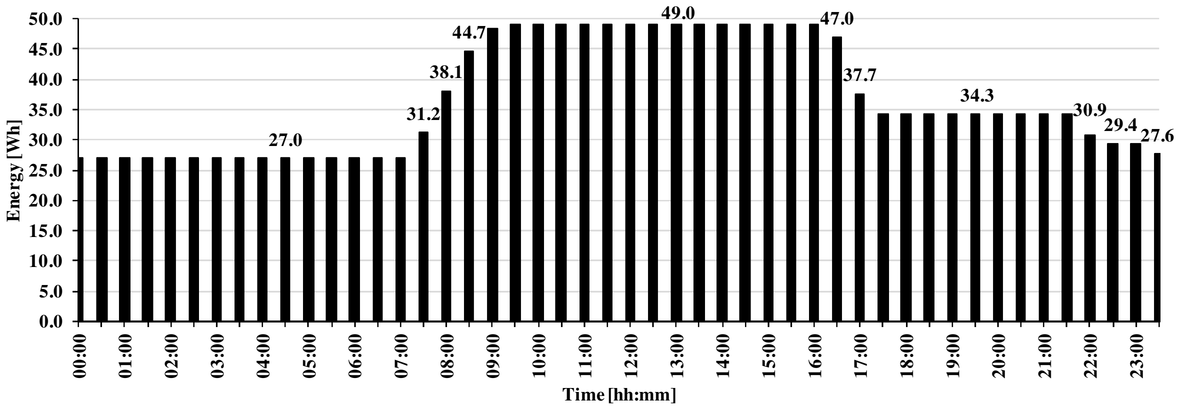

Figure 6.5: The simulated consumption profile for the working week usage profile of a computer.

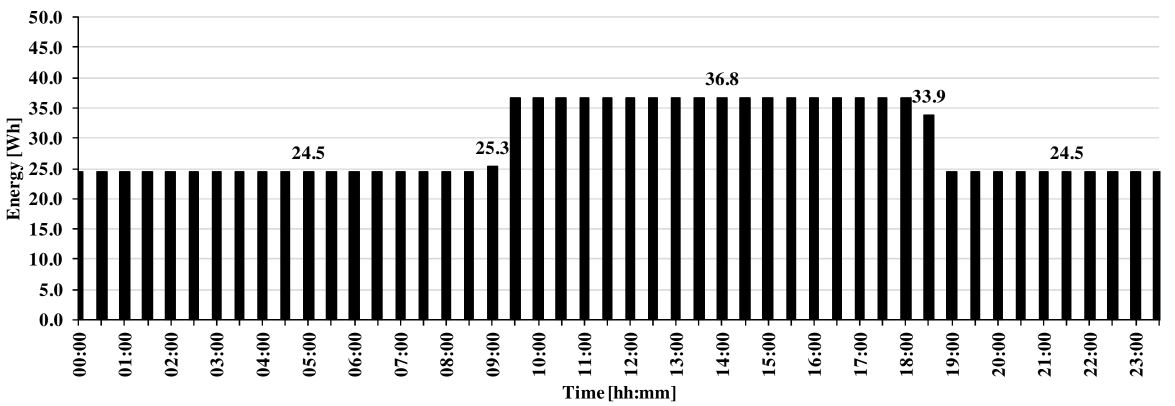

Figure 6.6: The simulated consumption profile for the Saturday usage profile of a computer.

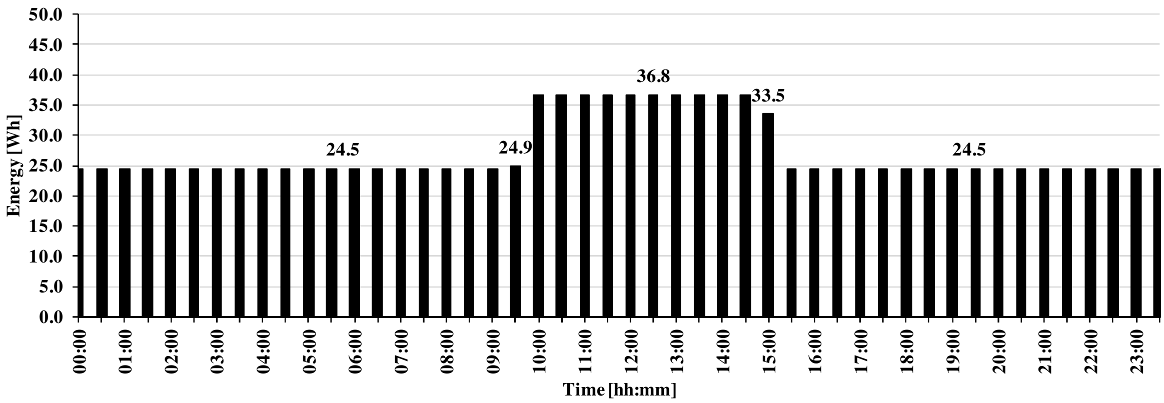

Figure 6.7: The simulated consumption profile for the Sunday usage profile of a computer.

6.2.3.2.2 Monitors

The variables of the simulated monitor are presented in Table 6.6. The monitor has a documented rating of 45 W and a calculated α-value of 85.6 %; the assigned usage profiles for the working week, Saturday and Sunday are presented in Figure C-15, Figure C-16 and Figure C-17 respectively. The simulated consumption for the working week and Saturday are presented in Figure 6.8 and Figure 6.9 respectively. The Sunday consumption is not presented, as the usage profile shows no activity. The calculated values are presented in Figure F-3.

Table 6.6: Variables of the simulated monitor.

Rating (P) [W]	α -value	Usage Profile	
45.0	58.6	Mon. – Fri.	Figure C-15
		Sat.	Figure C-16
		Sun.	Figure C-17

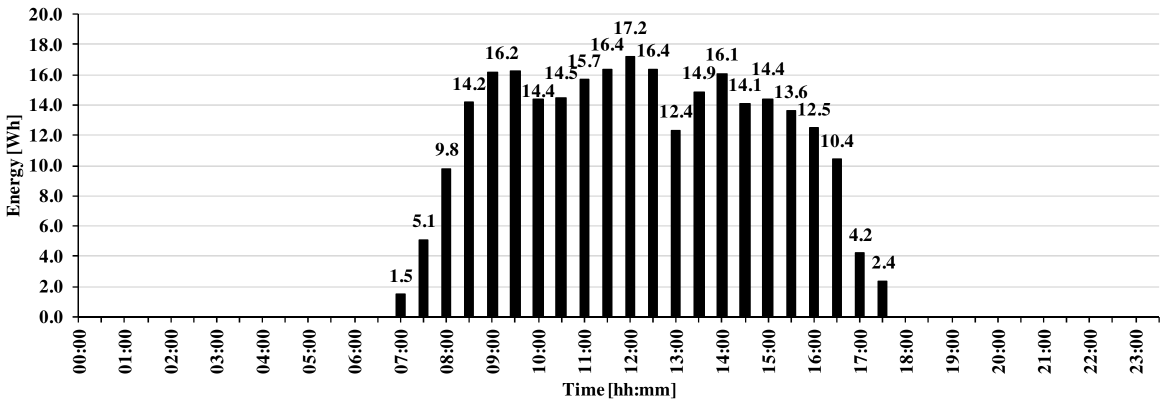

Figure 6.8: The simulated consumption profile for the working week usage profile of a monitor.

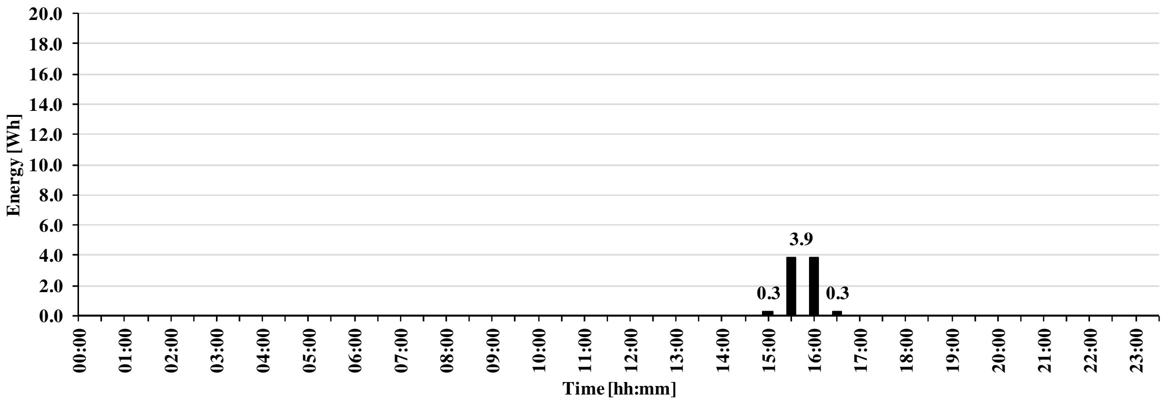

Figure 6.9: The simulated consumption profile for the Saturday usage profile of a monitor.

6.2.3.3 Lighting

The lighting functional class presents the simulated consumption for the lamps and the luminaires. It was only necessary to simulate one lamp and luminaire, as it is the data retrieval from the database that was to be verified.

6.2.3.3.1 Lamp

The variables of the simulated lamp are presented in Table 6.7. The lamp has a documented rating of 13.0 W and a calculated α-value of 90.0 %; the assigned usage profiles for the working week, Saturday and Sunday are presented in Figure C-12, Figure C-13 and Figure C-14 respectively. The simulated consumption for the working week, Saturday and Sunday are presented in Figure 6.10, Figure 6.11 and Figure 6.12, respectively. The calculated values are presented in Figure F-4.

Table 6.7: Variables of the simulated lamp.

Rating (P) [W]	α -value	Usage profile	
13.0	90.0	Mon. – Fri.	Figure C-12
		Sat.	Figure C-13
		Sun.	Figure C-14

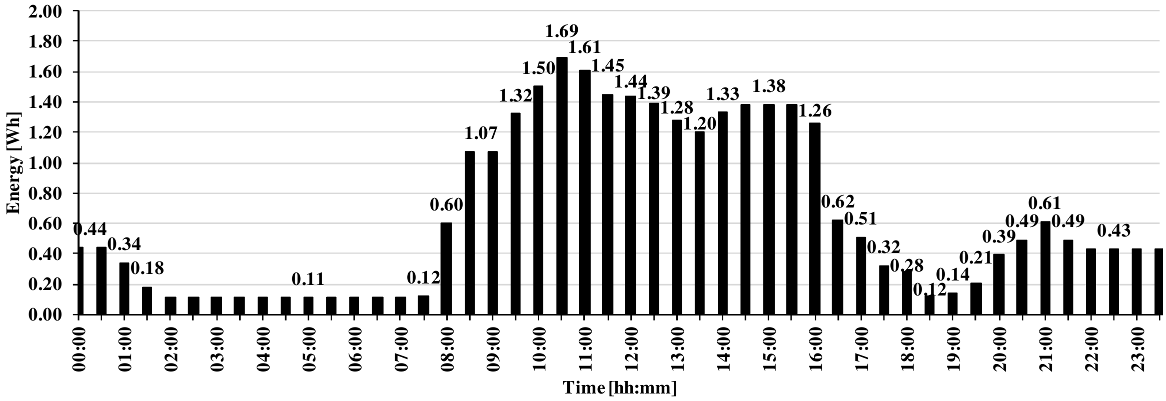

Figure 6.10: The simulated consumption profile for the working week usage profile of a lamp.

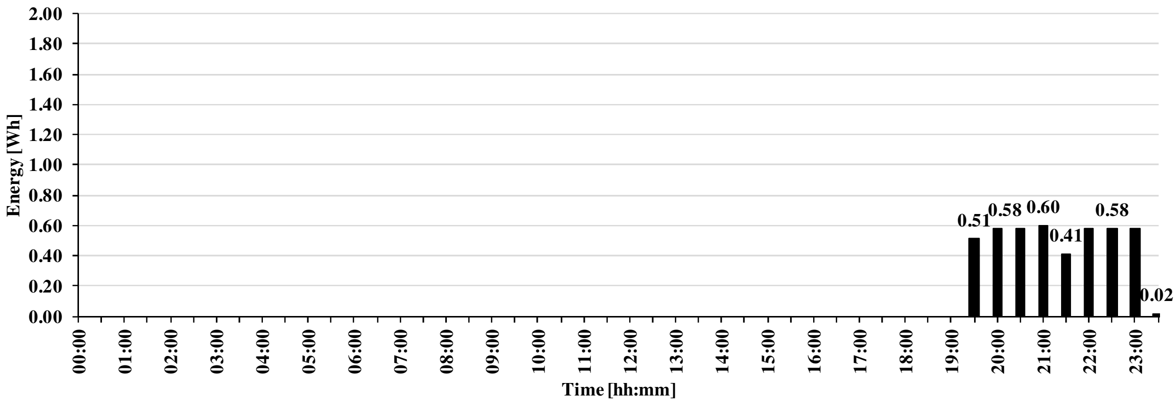

Figure 6.11: The simulated consumption profile for the Saturday usage profile of a lamp.

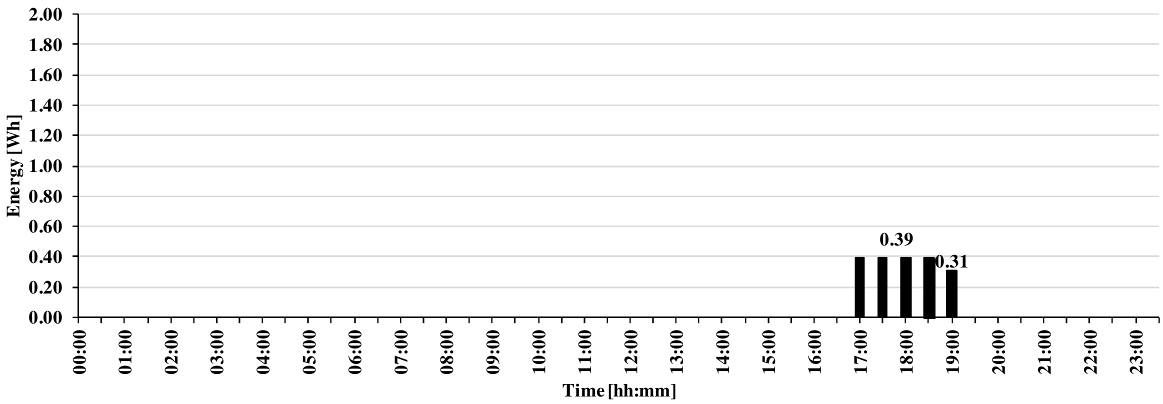

Figure 6.12: The simulated consumption profile for the Sunday usage profile of a lamp.

6.2.3.3.2 Luminaires

The variables of the simulated luminaire (consisting of two lamps and ballasts) are presented in Table 6.8. Each lamp has a documented rating of 40.0 W, resulting in a documented rating for the luminaire of 80.0 W. The calculated α-value for each lamp and ballast, combined, is 100 %. The assigned usage profiles for the working week, Saturday and Sunday are presented in Figure C-12, Figure C-13 and Figure C-14 respectively. The simulated consumption profiles for the working week, Saturday and Sunday are presented in Figure 6.13, Figure 6.14 and Figure 6.15 respectively. The calculated values are presented in Figure F-5.

Table 6.8: Variables of the simulated luminaire.

Rating (P) [W]	α-value	Usage profile	
80.0	100.0	Mon. – Fri.	Figure C-12
		Sat.	Figure C-13
		Sun.	Figure C-14

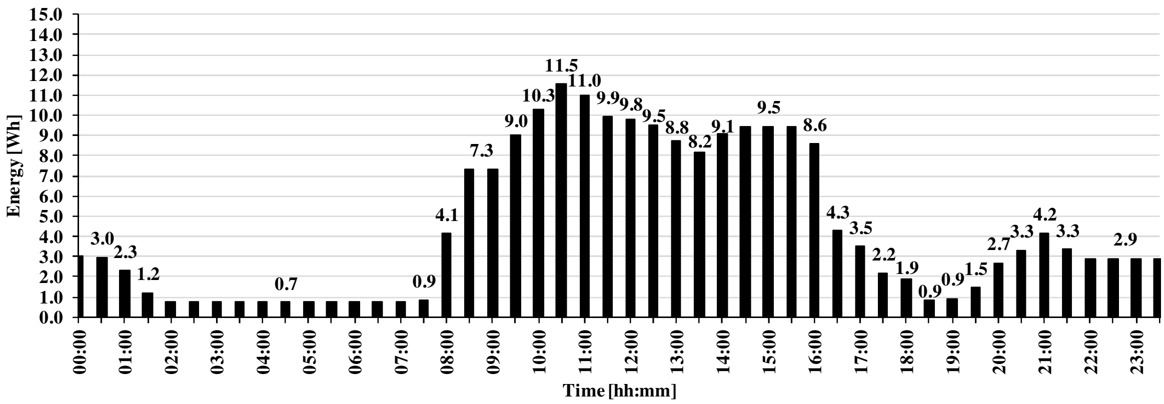

Figure 6.13: The consumption profile for the working week usage profile of a luminaire.

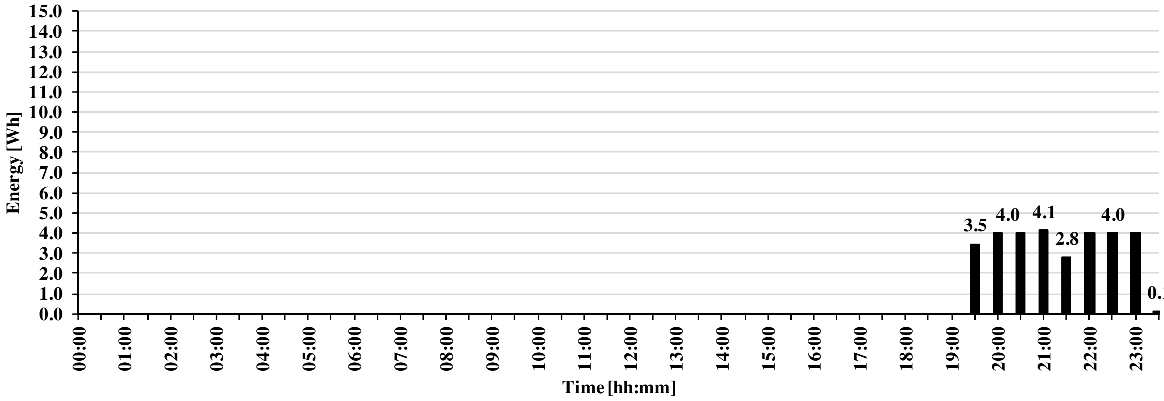

Figure 6.14: The consumption profile for the Saturday usage profile of a luminaire.

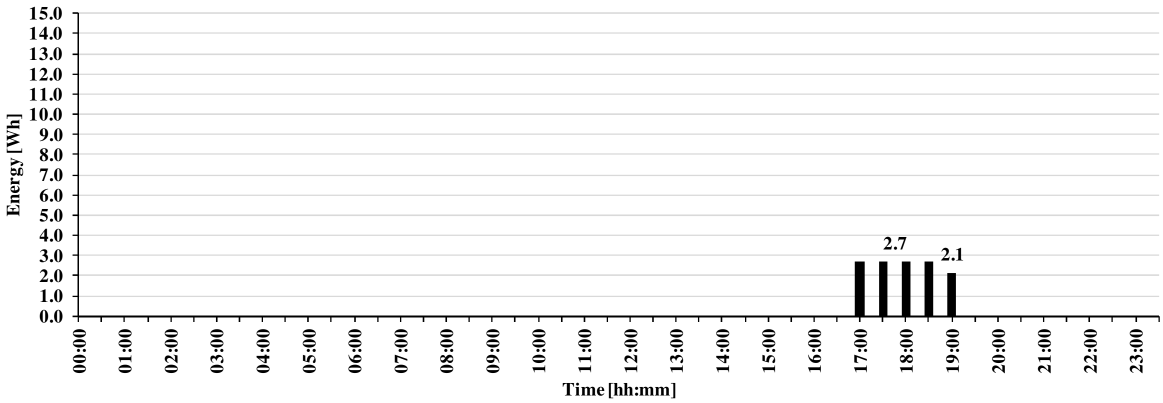

Figure 6.15: The consumption profile for the Sunday usage profile of a luminaire.

6.2.4 Conclusion

The usage profile algorithm as well as the usage profile averaging was implemented successfully – the usage profile calculated by the usage profile application, as presented in Figure 6.1, matched the manually calculated values in the fourth row of Table 6.1. As for the implementation of the usage profile adding and averaging, the usage profile presented in

Figure 6.2 coincides with the manually calculated values in Table 6.3, verifying the implementation of the equations presented in section 3.3.2.1. The simulated consumption profiles presented in section 6.2.2 coincide with the calculated values presented in Appendix F, which provides verification that the consumption algorithms, presented in section 3.3.3, were implemented correctly and that further simulation can be conducted.

6.3 Case study

6.3.1 Overview

The case study was conducted on the third floor of the E&E Engineering Faculty of the University of Stellenbosch, as this site best resembles a commercial building environment. The main objectives of the case-study were to

- Complete a load survey.
- Compare measured consumption data with the simulated results.
- Provide a consumption break down, based on the functional classes.
- Implement an energy management scenario.

The results obtained for each of the above mentioned objectives are discussed below.

6.3.2 Load survey

In order to implement a successful load survey, a floor plan of the surveyed area was required to determine the scope of the survey and assist in tracking the completion of the survey. The floor plan for the third floor is presented in Figure G-1, indicating each area and its assigned classification and designation.

The load survey was conducted manually to ensure a hard copy of the data, after which the data was imported into the application. The loads surveyed were extracted from the database and are presented in Figure G-2 to Figure G-11.

6.3.3 The comparison of the actual and simulated results

6.3.3.1 Overview

A section of the third floor was isolated and data loggers were installed to log the actual consumption from 5 – 22 November 2011. The isolated section's power supply is fed from the eastern and western side of the building. The distribution boards are indicated by A and B in Figure G-1 and the areas fed by each of the distribution boards contain a reference to the associated distribution board. The consumption profiles obtained from the eastern and western distribution boards were compared to the simulated consumption profiles in order to determine the accuracy of the results produced by the application. The consumption comparison for each of the distribution boards is presented and discussed in the remainder of this section.

6.3.3.2 Eastern distribution board

The data logger in the eastern distribution board was installed from 5 – 22 November 2011, providing two complete weeks of consumption data. The consumption data is presented for each week (6 – 12 November and 13 – 19 November). For illustration purposes, the simulated consumption is presented as a line graph and envelopes the measured consumption profile, as shown in Figure 6.16 and Figure 6.19. The discrepancies between the measured and actual consumption in Figure 6.16 and Figure 6.19 are encircled and numbered and will be discussed in the remainder to this section.

6.3.3.2.1 06 – 12 November 2011

Figure 6.16 presents the actual and simulated consumption for the first week (6 – 12 November 2011). Figure 6.17 presents the consumption of each functional class, expressed as a percentage of the total simulated consumption. Figure 6.18 shows the air conditioners' consumption, together with the ambient temperature profile, indicating the air conditioners' temperature dependency. The discrepancies between the actual and simulated consumption are due to the following causes:

- *A and G*: These discrepancies coincide with Saturday and Sunday respectively. The usage profiles were not calculated from switching profiles representative of the period presented, and thus do not incorporate the switching profiles associated with these specific days. However, weekends should be treated as special cases as they are not part of the conventional working week and occupants are not required to be present at the office.
- *B and D*: The difference in the simulated and actual consumption between 07:00 and 11:00 and then again between 15:00 and 18:00 on Monday to Friday is due to the variation in occupants arriving at and leaving the facility. This discrepancy is due to the academic nature of the facility, allowing for more flexible working hours than in a 'conventional' commercial environment.
- *C*: The increase in the simulation consumption between 19:00 and 00:00 is due to the usage profile incorporating occupants returning to the facility in the evening.
- *E*: This discrepancy occurs due to increased occupancy activity and is not due to increased air conditioner activity, as the 9th was a 'cool' day. Figure 6.18 shows the temperature and actual consumption profiles.
- *F*: The decrease in the consumption between 00:00 and 02:00 is due to the usages profiles applied, which were not calculated from switching profiles representative of the period. The discrepancy between 02:30 and 07:00 is due to a variation in the amount of computers left *ON* during the night. The amount of switched *ON* computers varies from day to day as can be seen from the variations in consumption for this period during each of the days.

6.3.3.2.2 13 – 19 November 2011

Figure 6.19 presents the actual and simulated consumption for the second week (13 – 19 November 2011). Figure 6.20 presents the consumption of each functional class, expressed as a percentage of the total simulated consumption. Figure 6.21 shows the air conditioners' consumption, together with the ambient temperature profile, indicating the air conditioners' temperature dependency. The discrepancies in the actual and simulated consumption are due to the following reasons:

- *A and I*: The discrepancies are similar to A and F in Figure 6.16. The discrepancy in *I* indicates the irregularity of a weekend that can only be incorporated when the switching profiles for the required period are used. The drastic discrepancy in *I* will, however, not be completely simulated as the usage profiles present average usage profiles and cannot accommodate such drastic changes in the consumption pattern.
- *B and D*: These discrepancies are similar to B and D in Figure 6.16.
- *E, F and H*: These three discrepancies are due to a significant increase in temperature on the 16th, 17th and 18th of November 2011, evident in Figure 6.21. The air conditioning units showed an increase in consumption; however the usage profile assigned to the units was not calculated from switching profiles representative of the period. This resulted in the significant difference between the actual and simulated consumption.
- *C*: The higher actual consumption is due to the usage profile applied not being calculated from switching profiles representative of the period.
- *G*: This discrepancy is similar to the discrepancy *E*, in Figure 6.16.

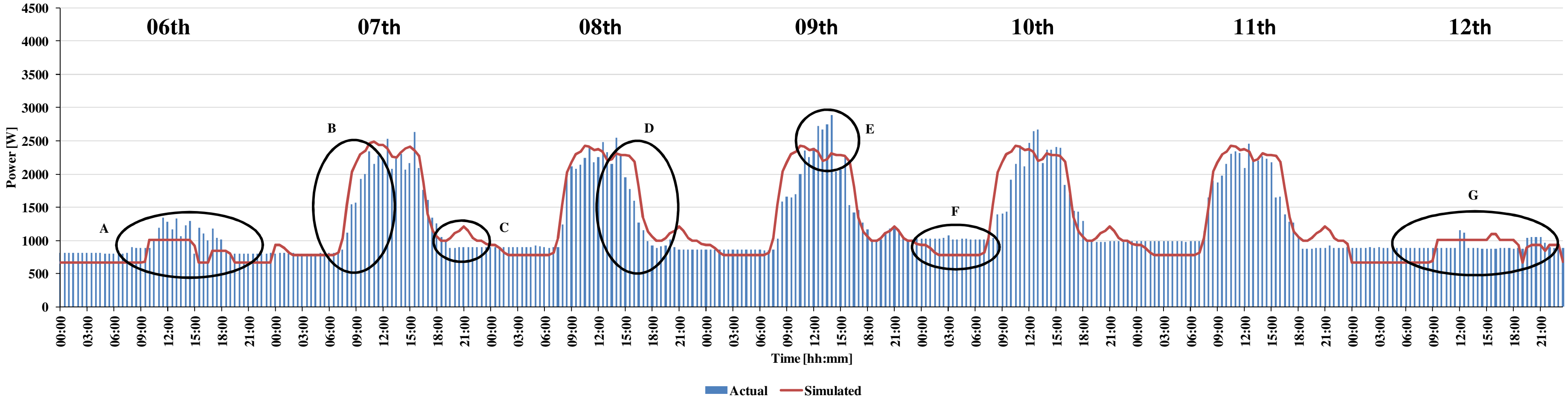

Figure 6.16: The actual and simulated consumption for the first week, 6 – 12 November 2011.

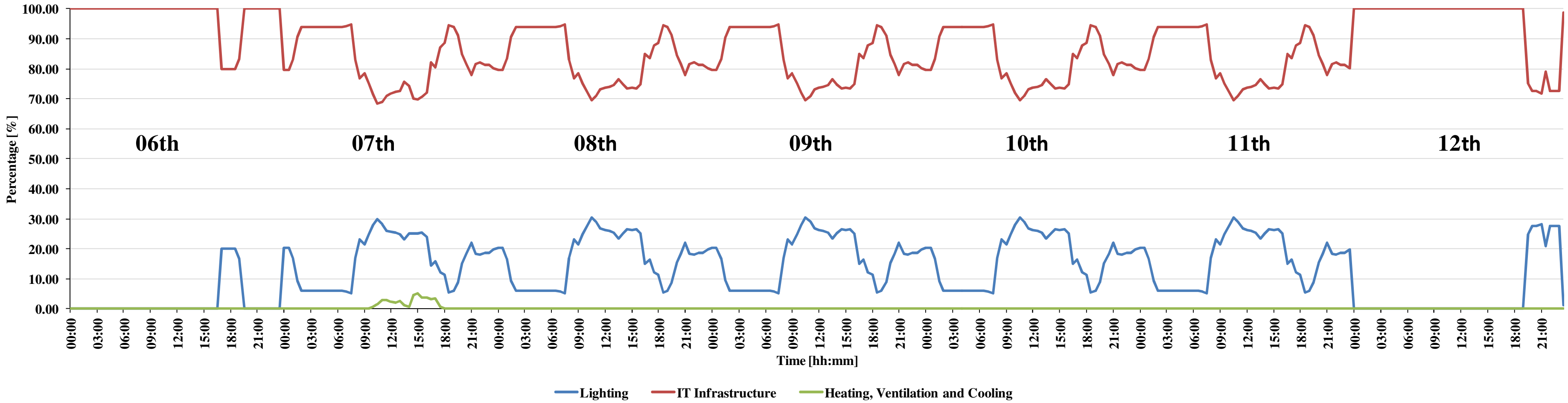

Figure 6.17: The consumption of each functional class, expressed as a percentage of the total simulated consumption, for 6 – 12 November 2011.

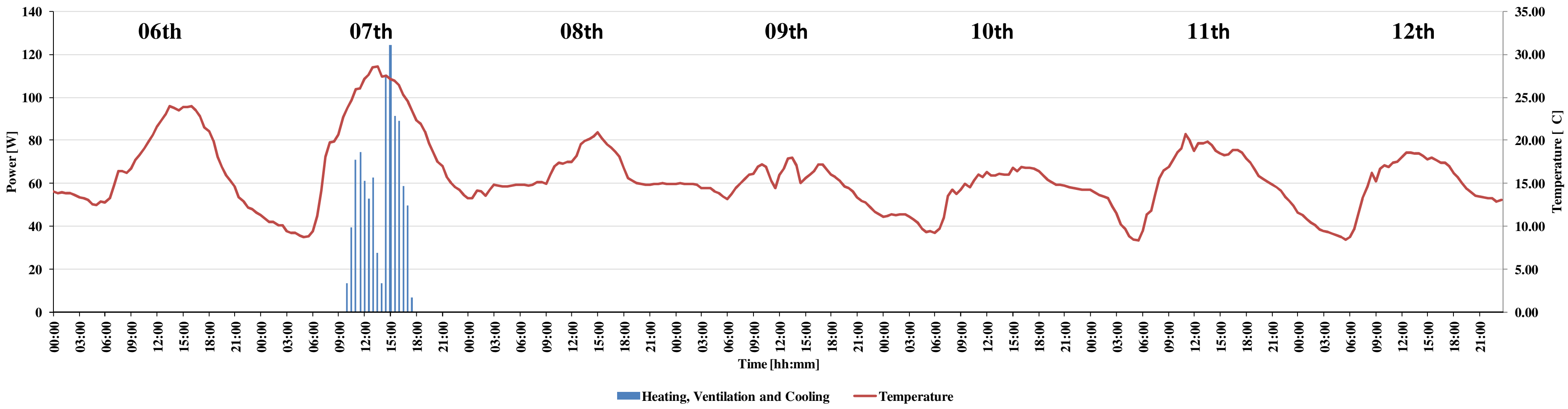

Figure 6.18: The consumption of the air conditioners, together with the ambient temperature profile, for 6 – 12 November 2011.

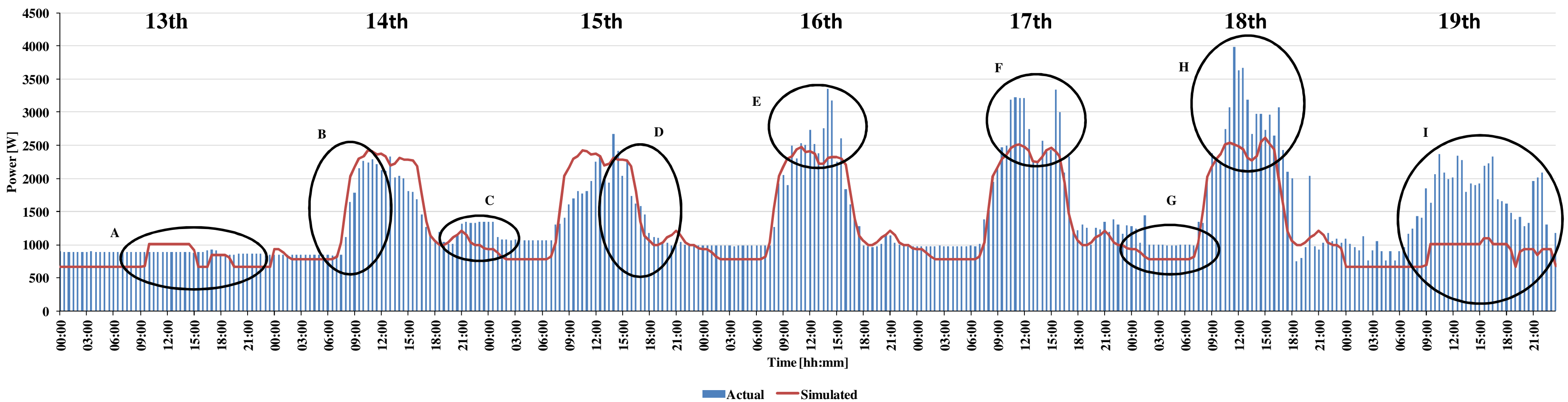

Figure 6.19: The actual and measured consumption for the second week, 13 – 19 November 2011.

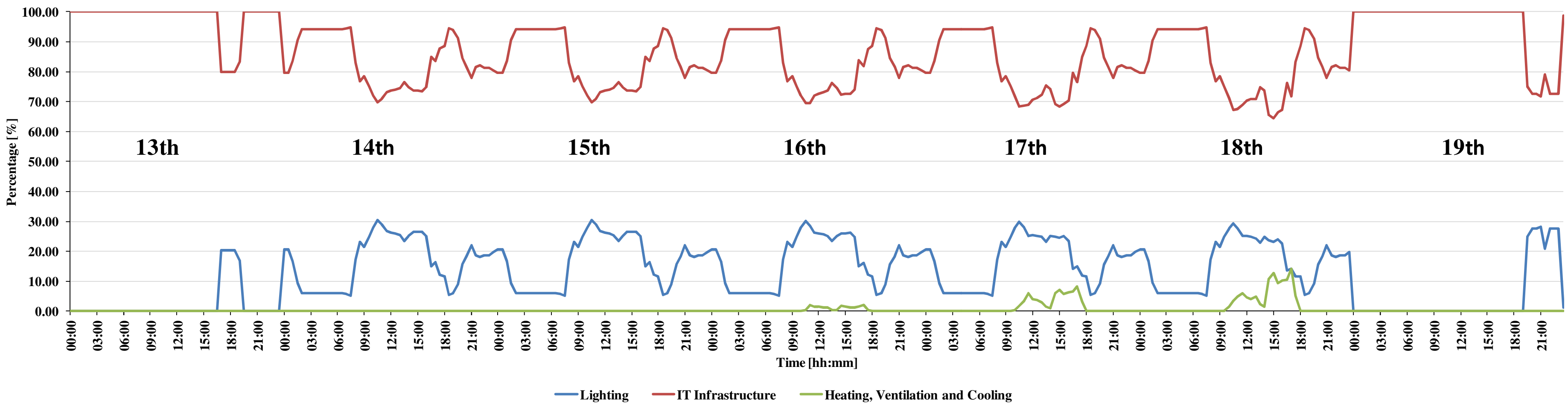

Figure 6.20: The consumption of each functional class, expressed as a percentage of the total simulated consumption, for 13 – 19 November 2011.

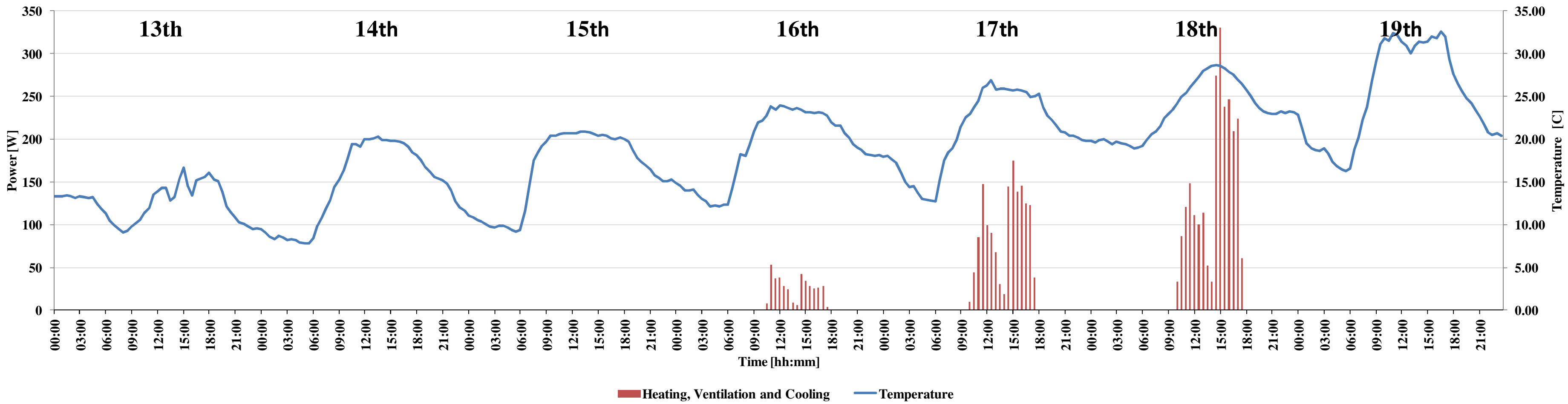

Figure 6.21: The consumption of the air conditioners, together with the ambient temperature profile, for 13 – 19 November 2011.

6.3.3.3 Western distribution board

The data logger in the western distribution board was installed from 5 – 22 November 2011, but experienced a hardware malfunction and could only provide four days of consumption data. Figure 6.22 presents the actual and simulated consumption for 6 – 9 November 2011. There is a considerable discrepancy in the simulated and actual consumption that cannot be ascribed to user behaviour. To eliminate temporary loads, a second measurement was made from 24 – 28 November. Figure 6.23 presents the actual and simulated consumption for 24 – 28 November 2011. The discrepancy evident in Figure 6.22 is also present in Figure 6.23, indicating that the initial discrepancy was not the result of temporary loads. After confirming that the consumption discrepancy was due to a load not included in the original load survey, the applicable areas were re-visited. It was found that one area had an Ethernet switch installed, not included in the original survey, which has a documented rating of 650 Watt. Figure 6.24 and Figure 6.25 present the simulated consumption profiles obtained after adding the documented rating of the switch to the simulated profiles in Figure 6.22 and Figure 6.23. The additional discrepancies between the measured and actual consumption in Figure 6.24 and Figure 6.25 are encircled and numbered and are discussed in the remainder of this section.

6.3.3.3.1 6 – 9 November 2011

The discrepancies in Figure 6.24 between the actual and adapted simulated consumption profiles, are discussed below in relation to their causes.

- *A*: The higher consumption can be due to increased air conditioner activity, as higher temperatures were experienced. Figure 6.26 presents the temperature and the actual consumption. Besides higher air conditioner activity, the 27th was a Monday, which could also have contributed towards the increased consumption as most people are present on Mondays.

- *B and C*: These discrepancies occurred after the occupants had left the facility and are due to a greater number of computers being switched *OFF* than in the usage profile used during the simulation.

6.3.3.3.2 24 – 28 November 2011

The discrepancies in Figure 6.25 between the actual and adapted simulated consumption profiles can be linked to the following causes:

- *A and C*: The temperature profile, presented in Figure 6.27, was not exceptionally high for the 24th and the 25th, indicating that *A* and *C* are due to increased user activity.
- *B* occurs when the occupants have left the facility and is due to a greater number of computers being switched *OFF* than included in the assigned usage profile..
- *D* is due to the higher temperatures experienced during the 25th. Figure 6.27 presents the temperature and the actual consumption. The increased consumption could also be due to increased user activity, as the 28th was a Monday.

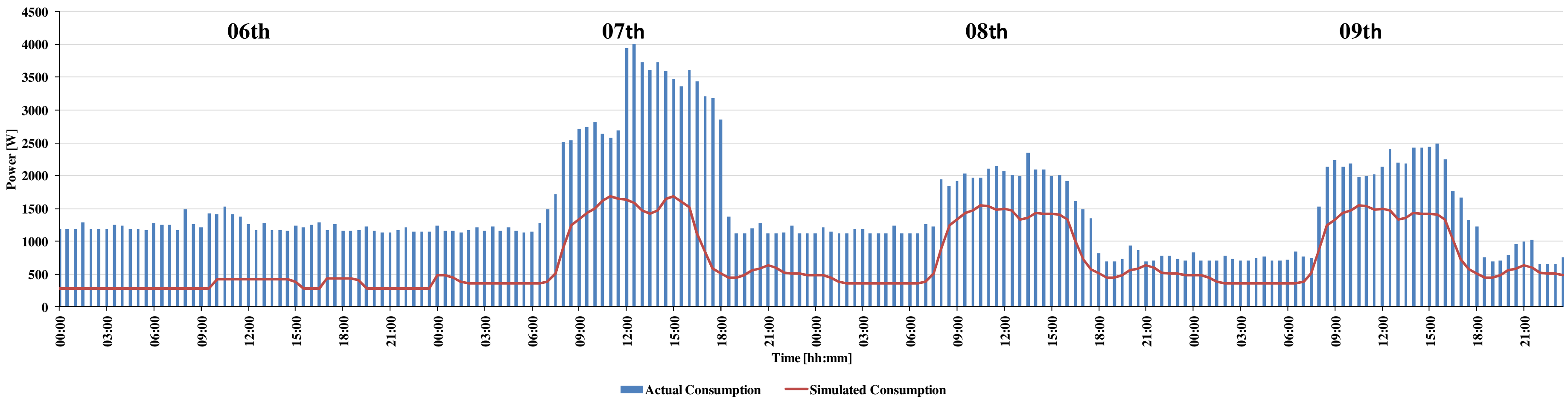

Figure 6.22: The measured and simulated consumption for 6 – 9 November 2011.

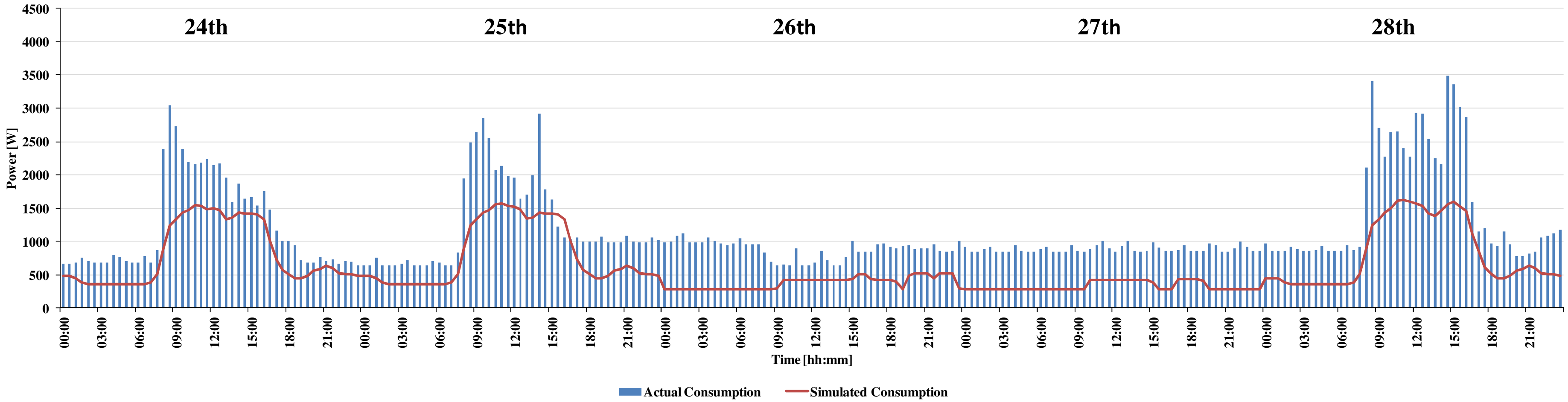

Figure 6.23: The measured and simulated consumption for 24 – 28 November 2011.

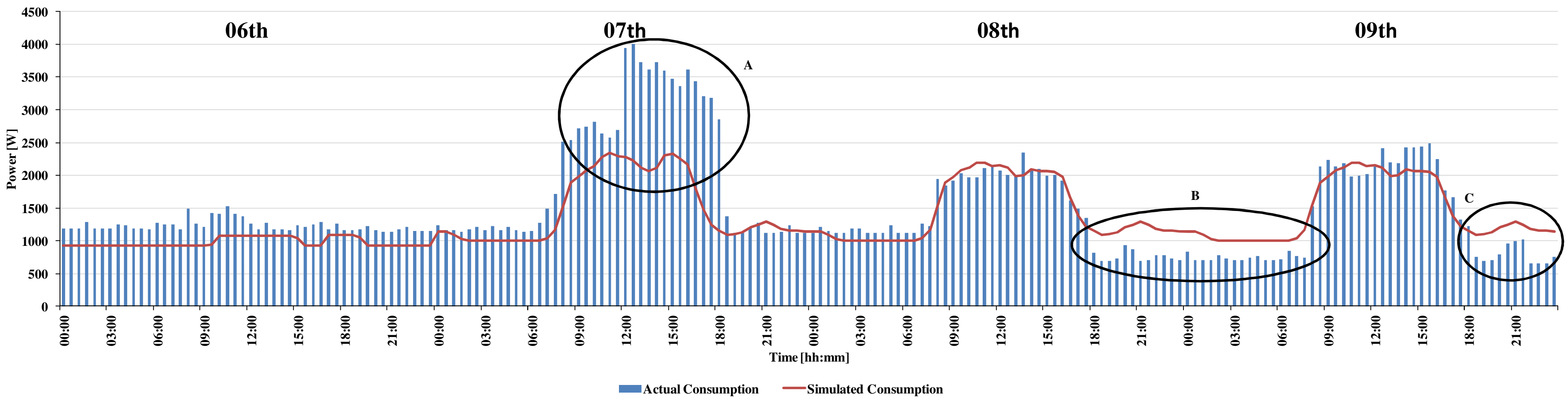

Figure 6.24: The measured and altered simulated consumption for 6 – 9 November 2011.

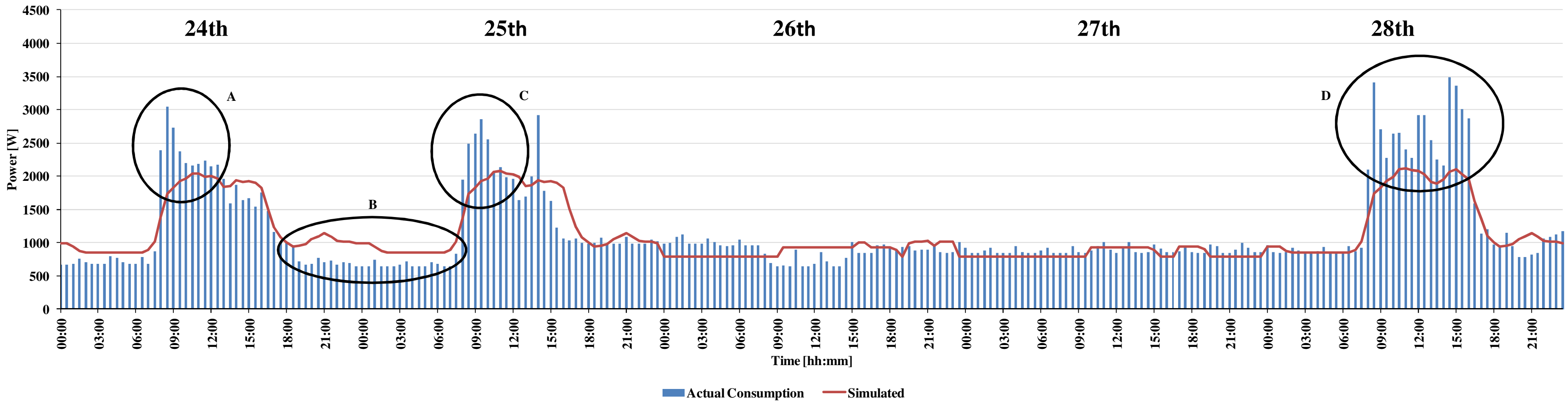

Figure 6.25: The measured and altered simulated consumption for 24 – 28 November 2011.

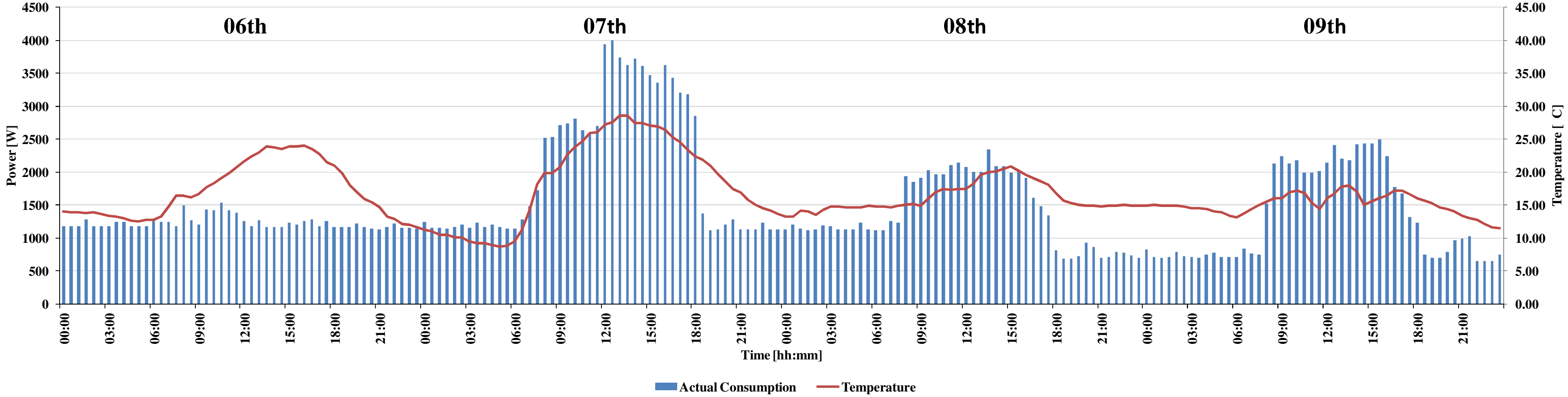

Figure 6.26: The actual consumption and the temperature profile for 6 – 9 November 2011.

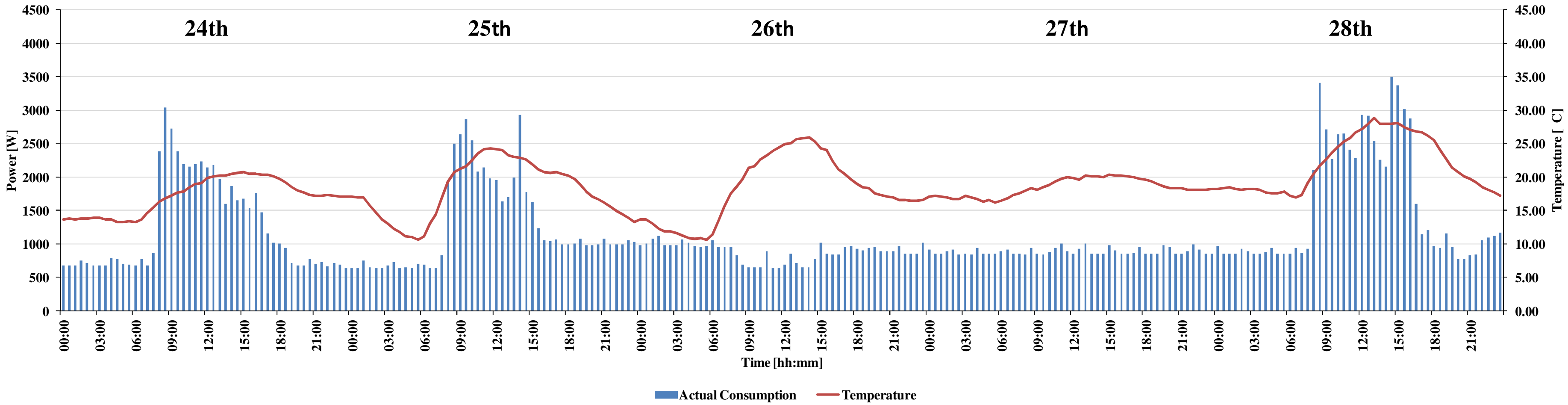

Figure 6.27: The actual consumption and the temperature profile for 24 – 28 November 2011.

6.3.4 Scenario implementation

In addition to simulating the consumption for a project, users can alter surveyed loads without altering the original surveyed data. These load alterations allows for savings to be investigated and assist facility managers with the implementations of an energy management plan. The IT department of the University of Stellenbosch is currently considering the implementation of a work station power management program. The technology exists and can be implemented, but the savings cannot be quantified without an established base line [31].

By simulating only the IT infrastructure for the isolated section, a base line can be determined. Figure 6.16 and Figure 6.19 above show a steady consumption after the end of the working day, which is mostly contributed by computers that are not switched *OFF*, as evident in Figure 6.17 and Figure 6.20. The savings can be simulated by assigning altered usage profiles to the computers, taking into account the period for which the computer are switched *OFF*. Figure 6.28, Figure 6.29 and Figure 6.30 present the implemented usage profiles to achieve savings, and represent the computers being switched *OFF* as follows:

- *Monday – Friday*: 00:00 – 07:30 and 17:30 – 00:00.
- *Saturday*: 00:00 – 08:30 and 19:00 – 00:00.
- *Sunday*: 00:00 – 09:00 and 15:30 – 00:00.

The simulated total consumption for 13 – 19 November 2011, with the altered computer usage profiles, is presented in Figure 6.31. Altering the usage profiles of the computer as presented in Figure 6.28, Figure 6.29 and Figure 6.30 results in a 750 W saving per half hour during the evening and are presented by *A* in Figure 6.31. These alterations present an energy management opportunity that can easily be implemented, but the following cases would have to be considered:

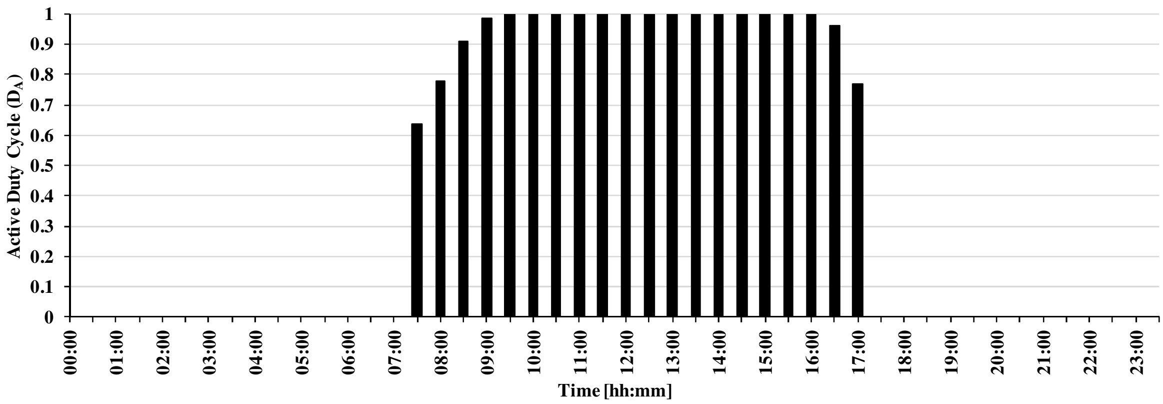

Figure 6.28: The altered working week usage profile for computers.

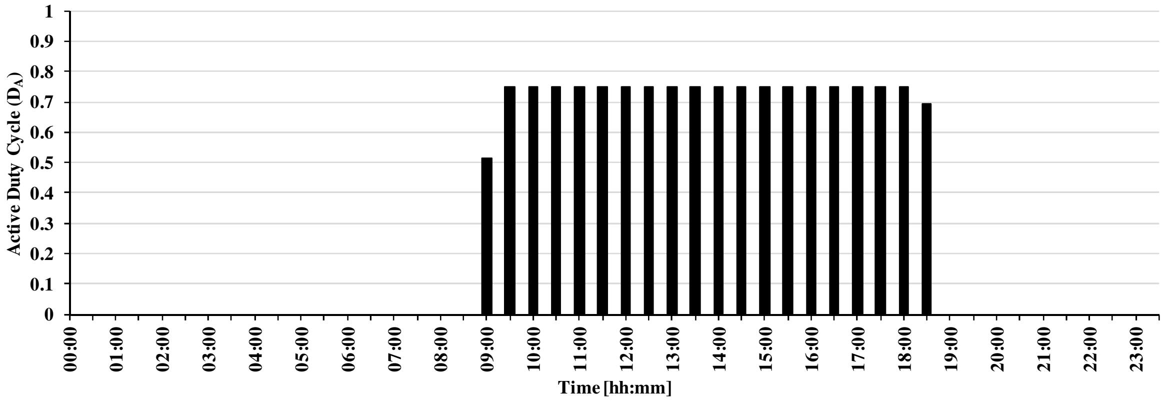

Figure 6.29: The altered Saturday usage profile for computers.

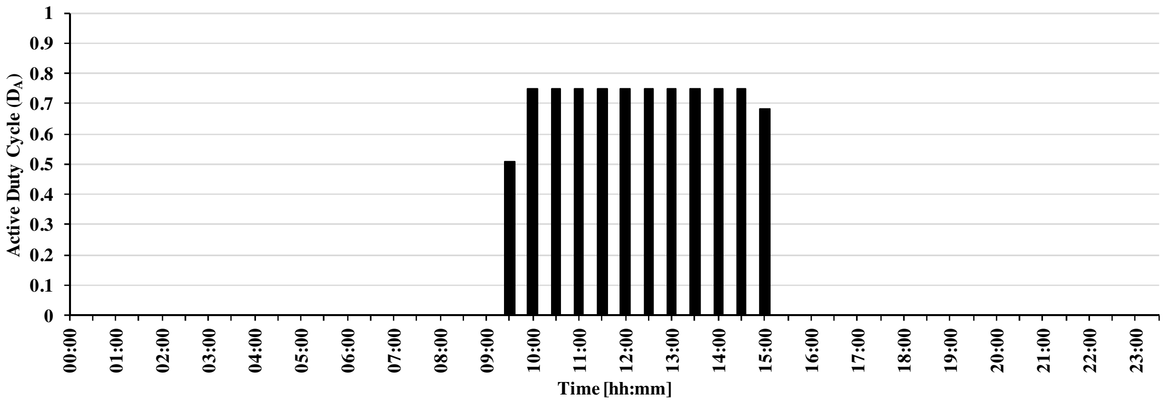

Figure 6.30: The altered Sunday usage profile for computers.

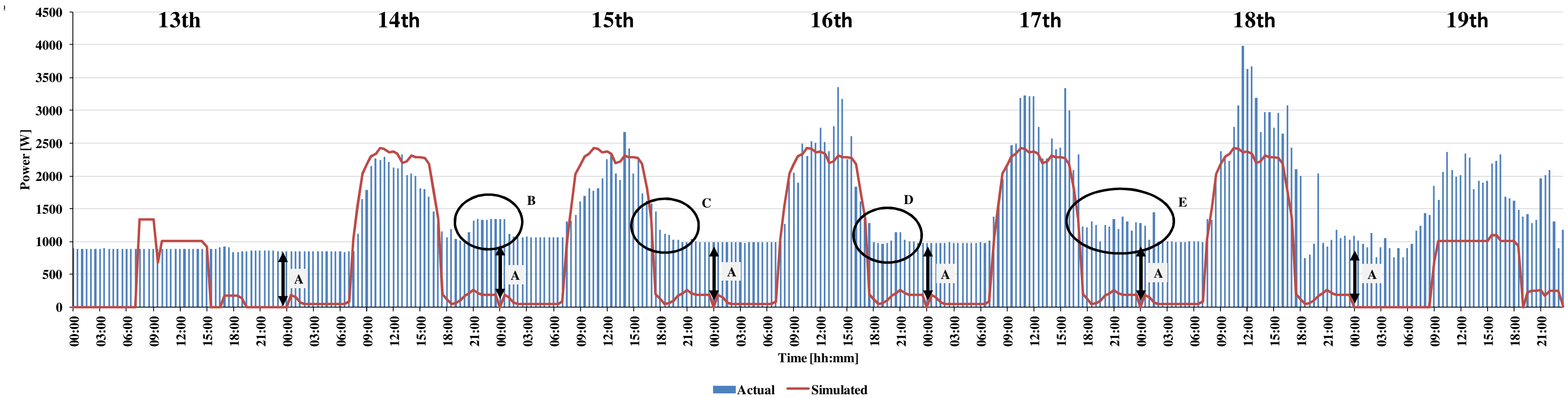

Figure 6.31: The actual and altered simulation consumption profiles for 13 – 19 November 2011.

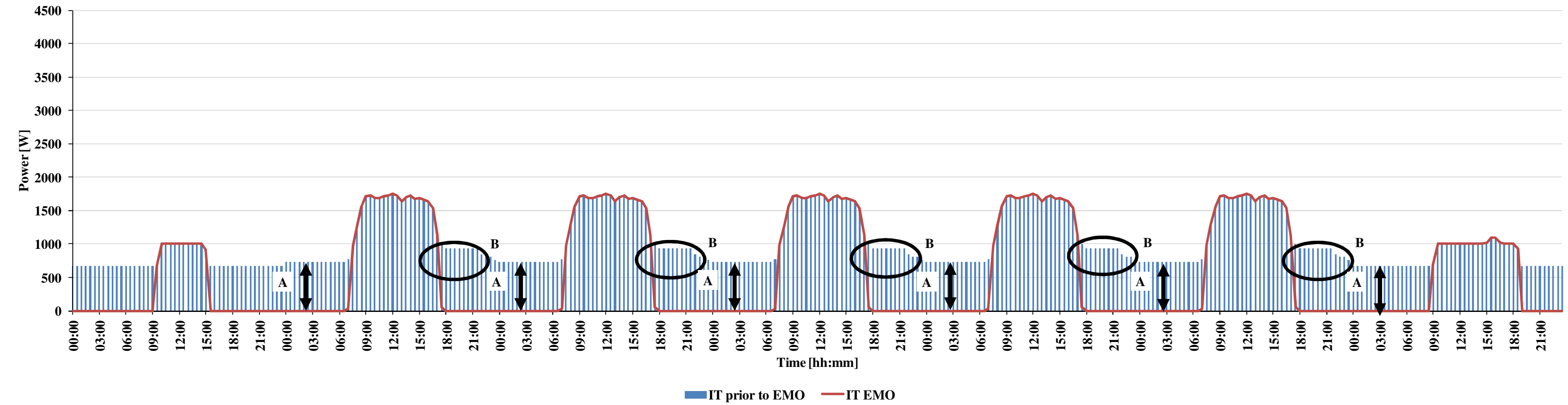

Figure 6.32: The simulated consumption with the old and altered computer usage profiles for 13 – 19 November 2011.

- If computers are to be switched *OFF* at 17:30 during the working week, how are occupants leaving after 17:30 accommodated, as presented by *C* and *E* in Figure 6.31.
- Once occupants leave the facility, some return in the evening, requiring certain computers to be switched *ON,* as seen in *B*, *D* and *E* in Figure 6.31.
- The weekend is a special case, as there is no general pattern that applies. Occupants work during the weekend, but the frequency varies and no two weekends are the same, which is evident from the 19th, presented in Figure 6.32.

However, these discrepancies are not directly related to the IT infrastructure. To determine the base line for the IT infrastructure, the relevant loads were simulated with the initial usage profiles and then with the altered usage profile. Figure 6.32 presents the IT infrastructure base line together with the consumption profile obtained through the altered usage profiles. The savings are indicated by *A* and the discrepancies that are caused by the IT infrastructure are presented by *B* [31].

The current technology accommodates the discrepancies presented in Figure 6.32 as follows:

- Monitors time out after 30 minutes.
- Disks time out after 60 minutes and are completely stopped.
- Systems enter standby after 120 minutes.
- System hibernates after 180 minutes.

With the savings achieved, the power management programme is a viable EMO that can be successfully implemented.

This case study is one of many that can be conducted on surveyed data and clearly illustrates the insight that can be gained from executing scenarios that can greatly increase the effectiveness with which energy manage plans are implemented.

6.3.5 Conclusion

The loads surveyed were sufficient to simulate the consumption but larger loads, such as the Ethernet switch, should be included. Weekends can vary significantly and should be treated as special cases. Occupants are not required to be at the facility over weekends, resulting in significant discrepancies when occupants are present. The temperature dependant usage profiles of the air conditioning units should be obtained from switching profiles representative of the simulation period. This should be done to incorporate temperature variances unique to the simulation period.

Taking the above mentioned considerations into account, the simulated consumption provides sufficient results to determine the general consumption profile for working week days. These results are sufficient to develop an understanding of the consumption and determine the effects of EMOs.

7 CONCLUSIONS AND RECOMMENDATIONS

This chapter evaluates the set objectives and presents recommendations for future work.

7.1 Conclusions

7.1.1 Overview

The energy auditing application surpasses the initial expectations, provides an acceptable base line and allows for the effective and efficient breakdown of consumption. This tool provides facility managers with the means of quantifying savings, thus increasing the viability of demand-side interventions. This is achieved through accomplishing the following objectives that were set in Chapter 1:

- Develop a methodology to which an energy auditing application can be designed and implemented.
- Design a database and a client-side application to access the various tables.
- Conduct load research into *how* and *when* loads operate.
- Obtain actual consumption data and compare it to the simulated results to determine the accuracy with which the application simulates the actual consumption.
- Identify and asses an EMO.

The remainder of this section considers how each of these objectives where achieved.

7.1.2 The energy auditing methodology

The first step in designing the energy auditing methodology was to determine a structure according to which the audit could be implemented. Figure 7.1 presents the structure implemented, which was found to be adequate during the execution of the load survey.

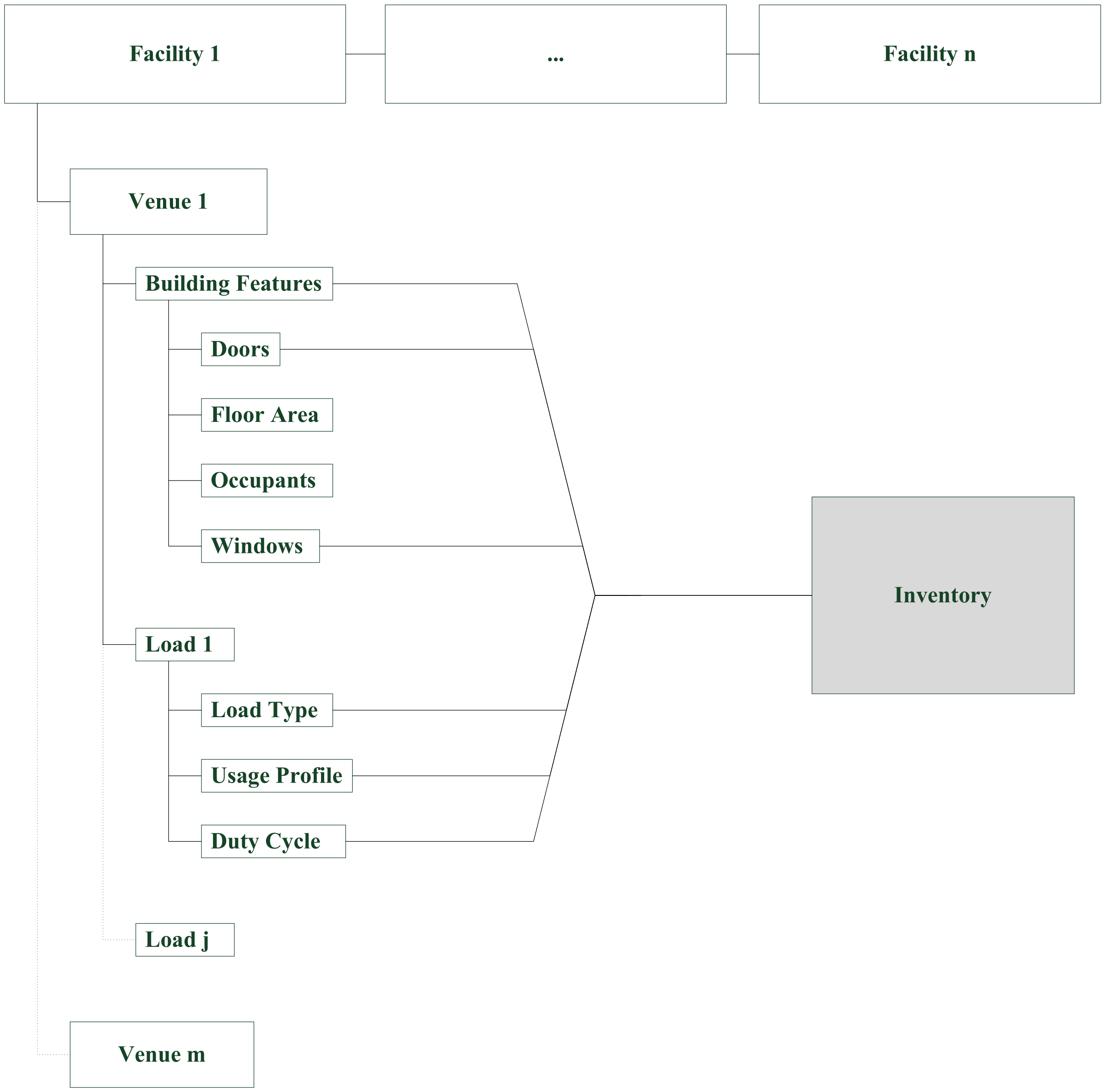

Figure 7.1: The structure according to which the energy audits where implemented.

Calculating the consumption required the users' behaviour to be determined, for which the switching profiles were defined. However, the continuous profile could not be used in the energy calculations, which necessitated the implementation of the usage profile.

In addition to the users' behaviour, the load has a documented rating which is scaled by the α–value to incorporate the actual power consumed by the load. In addition to the rating, the operational duty cycle was also defined. The equations required to calculate the consumption, combining the above mentioned variables, were also presented.

7.1.3 Database and client-side application design and documentation

The structure defined in Figure 3.1 was implemented by defining a project, to which areas were added. Once an area was added, the loads could be assigned from the central load inventory which contains all the available loads and profiles. The analysis was conducted by creating duplicate projects, referred to as *cases*.

The database tables designed incorporated the load inventory, provided the required functionality to implement the administrative requirements and enabled the cases to be analysed. The database design was documented by using Visio's native database components, which provided all the components required to accurately represent the database, the tables and the various relationships existing between the tables.

The client-side user interface navigated users seamlessly based on their permissions, accommodated the load inventory management and enabled analysis to be conducted efficiently. The GUI also ensured that data integrity was maintained from the load survey to the analysis, as the results obtained during the programme validation coincided with the manually calculated values. Documenting the GUI proved to be difficult as UML does not accommodate GUI representation. However, by combining use-case and activity diagrams the general functionality could be conveyed to the user.

7.1.4 Load research

The switching profiles were obtained by adding additional hardware to an existing logger and installing these loggers for various periods. Once the switching profiles, were obtained they were uploaded to an application which computed the usage profiles. The obtained usage profiles present averaged user behaviour, which is responsible for most of the discrepancies between the simulated and the actual consumption profiles.

7.1.5 Case study results

The results obtained from the application were not an exact match to the actual consumption profiles acquired by the data loggers. These discrepancies were expected and can be accounted for as the usage profiles present averaged user behaviour do not accurately present day-to-day variances. However, the simulated profiles present users with a good understanding of the base line consumption, information that is just as valuable as knowing which variances occurred. In addition to simulating the total consumption, the application enables the simulation of consumption levels for user defined scenarios and can consist of any number of loads. This functionality enabled the quantification of savings as the pre- and post-demand-side intervention consumption levels could be accurately determined. In view of the results obtained, it is concluded that the application is suitable for conducting energy audits.

7.1.6 Energy management opportunities

From the consumption profiles gained, it was found that a significant number of computers remained *ON* during the night. By altering the usage profiles assigned to the computers, the savings associated with the altered users' behaviour could be quantified. This provides the necessary support required for the expansion of the IT department's work station power management program.

7.2 Recommendations

7.2.1 Overview

Simulating the consumption by making use of usage profiles, duty cycles, and combining the α–values with the documented ratings, proved to simulate the consumption to a level acceptable for the current purpose. The greatest contribution to this work can be made by improving the load survey or adding additional analysis algorithms to the application. The proposed recommendations are discussed in the remainder of the section.

7.2.2 Load inventory expansion

The current application accommodates a limited number of load types and has a limited number of options available per type. Adapting the application to incorporate more load types will drastically increase the areas of application, while increasing the options available per load type will increase the accuracy of the simulation. In addition to increased accuracy, the number of demand-side interventions that can be assessed will also increase, expanding the energy saving possibilities.

The usage profiles available are limited and can be increased, which will provide a more accurate presentation of the users' behaviour. However, in the case where usage profiles are to be acquired on a large scale, the existing logger would have to be improved. Data is currently retrieved manually, which is time consuming. Adding hardware to enable remote data retrieval will enable the switching profiles of numerous facilities to be acquired, all from a central point, increasing the representation of user behaviour.

7.2.3 Additional analysis algorithms

The current application quantifies savings in terms of W or kWh, which is acceptable but can be improved. Adding algorithms that incorporate tariff structures will greatly assist in saving quantification and will provide a better understanding of the implications of the proposed demand-side interventions. In addition to quantifying savings in monetary terms, it is also desirable to obtain the emission impact associated with the energy savings.

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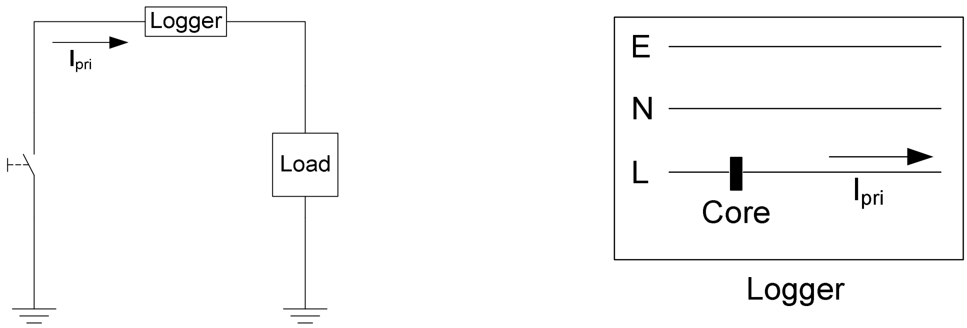
Appendix A STATE TRIGGERING CIRCUIT

A.1. Overview

To accurately obtain the switching profiles, an additional circuit was added to an existing state change logger. The logger is placed between the wall-socket and the electrical load as shown in Figure A-1(a), with the live connection re-wired through a magnetic core, as indicated in Figure A-1(b).



(a) (b)

Figure A-1: The logger position and the core placement.

Figure A-2 presents the additional circuit, to be added to the existing state logger.

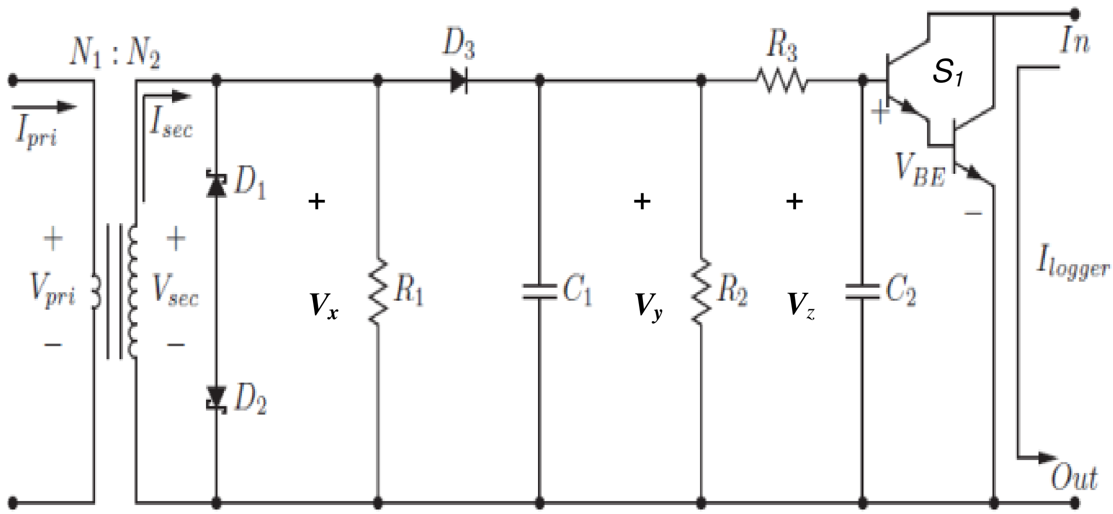


Figure A-2: Additional Circuit Added to State Change Logger.

The circuit presented in Figure A-2, consists of a magnetic core and a rectification circuit that is discussed in the remainder of the section. This section concludes with a switching profile for one week, gained from an air conditioning unit.

A.2. The Magnetic Core

To incorporate various electrical loads, the additional circuit was designed for:

$$100mA_{RMS} \leq I_{pri} \leq 16A_{RMS} \tag{A.1}$$

Assuming that the transformer is ideal:

$$I_{sec} = \frac{N_1}{N_2} I_{pri} \tag{A.2}$$

However, for a single primary winding, (A.2) simplifies to:

$$I_{\sec} = \frac{I_{pri}}{N_2} \tag{A.3}$$

$V_{\sec}$ induced, is given by:

$$\begin{aligned} V_{\sec} &= \frac{N_1 N_2 A_e \mu\omega |I_{pri}|}{l_e} \cos(\omega t) \\ &= \frac{N_2 A_e \mu\omega |I_{pri}|}{l_e} \cos(\omega t) \qquad (N_1 = 1) \end{aligned} \tag{A.4}$$

To be able to decide on which magnetic core to use, information regarding the secondary side is needed, of which the design will be discussed in the next section. $|V_{sec_{\min}}| = 2.1V$, given in Equation (A.11).

$\left|V_{\sec_{\min}}\right|$ is required at $\left|I_{pri_{\min}}\right|$. Substituting this condition into Equation (A.4) results in:

$$\left|V_{sec_{\min}}\right| = \frac{N_2 A_e \mu\omega \left|I_{pri_{\min}}\right|}{l_e} \tag{A.5}$$

A_e, μ and l_e are fixed depending on the core's dimensions as well as the material, leaving only N_2 variable.

The transformer selected, has a winding ratio of $1:2500$. The conditions at which the core saturates where determined by the short and open circuit test, the individual test circuits are presented in Figure A-3, with R_{load} replaced with a $1k\Omega$ resistor.

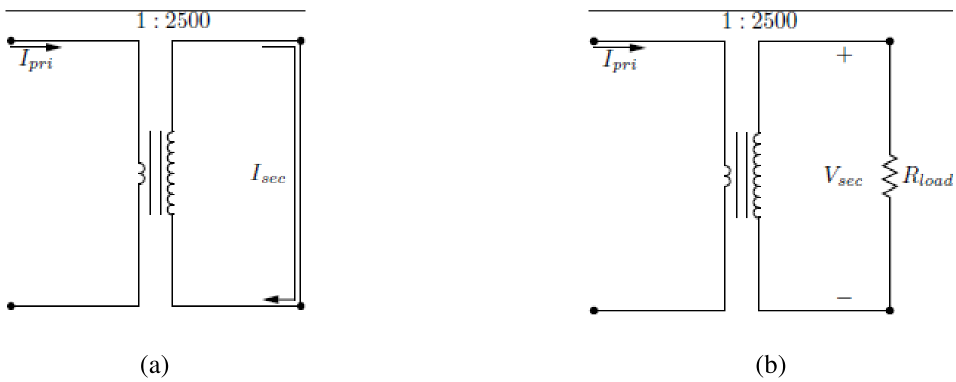


Figure A-3: The circuits for the short and open circuit test, respectively.

The measurements obtained from both these test are presented in Figure A-4. During the short circuit test, core saturation was reached at:

$$I_{\sec_{MAX}} = 7.12mA_{RMS}, \tag{A.6}$$

indicated by $I_{\sec_{MAX}}$ in Figure A-4. The open circuit test resulted in core saturation at:

$$V_{\sec_{MAX}} = 5.20V, \tag{A.7}$$

The required $V_{\sec}$ of 2.1 V is below $V_{\sec_{MAX}}$, preventing core saturation and eliminating irregular responses.

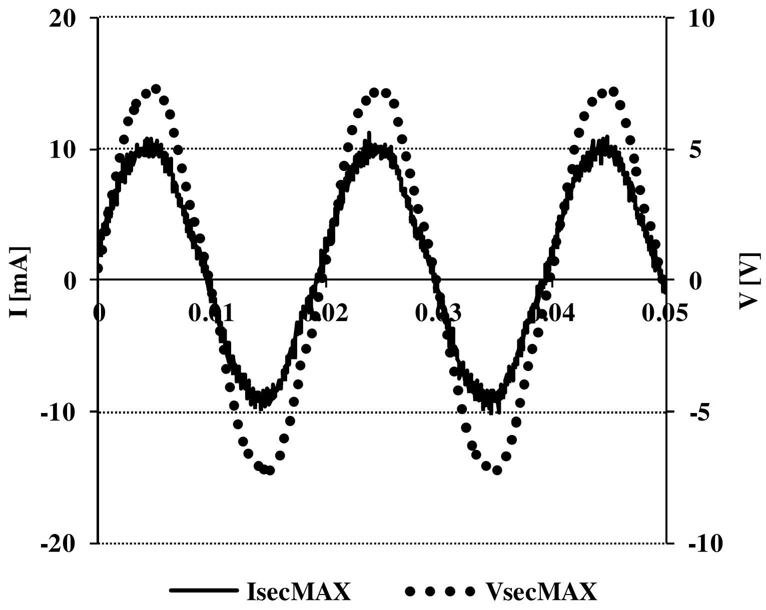


Figure A-4: Measurements obtained from the short and open circuit tests.

A.3. The Rectification Circuit

The rectification circuit presented in Figure A-2 consists of D_{1-3}, R_{1-3}, C_{1-2} and S_1. R_1 relates V_{sec} directly to I_{sec}. The open-circuit test provided the maximum secondary voltage, $V_{\sec_{\max}}$, and it must not be exceeded when $I_{pri_{\max}}$ is reached. To ensure that $V_{\sec_{\max}}$ is not reached, $D_{1,2}$ are placed in parallel with R_1, clamping V_{sec} at $3.9V$

Calculating R_1 requires V_{BE} and the switching voltage of S_1. Making use of a Darlington-pair provides significant gain, requiring less base current to switch. After clamping V_{sec}, the signal is rectified by a half-wave rectifier, consisting of C_1, D_3 and R_2, where:

$$C_1 = 1\mu F, \tag{A.8}$$

$$V_{ON-D_3} = 0.7V \; and \tag{A.9}$$

$$R_2 = 220k\Omega. \tag{A.10}$$

V_x is thus given by:

$$\begin{aligned} V_x &= V_{D_3} + V_{BE} \\ &= 2.1V \end{aligned} \tag{A.11}$$

By setting R_1 to $55k\Omega$, the data logger is switched at $I_{\sec_{\min}}$.

The rectified V_{sec} is then filtered, by R_3 and C_2 to achieve the desired time response.

$$C_2 = 1\mu F \ and \tag{A.12}$$

$$R_3 = 270k\Omega. \tag{A.13}$$

Figure A-5 presets both V_y, the unfiltered signal, and V_z, the filtered signal. The filtered signal, V_z, has less noise than V_y and is the preferred signal to be used for switching the transistor, S_1.

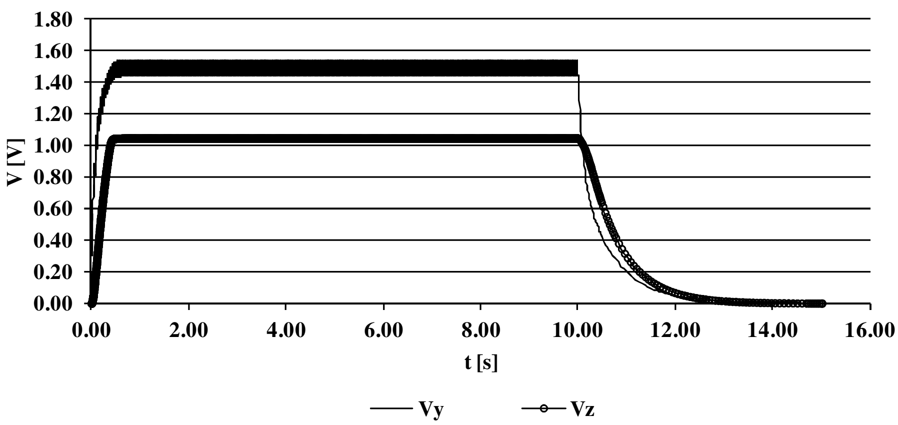


Figure A-5: The filtering effect of R_3 and C_2.

The conditions required for a state change are presented in Figure A-6, with:

$$I = 110.3mA_{RMS} \,, \tag{A.14}$$

and

$$V_{BE} = 0.96V \,. \tag{A.15}$$

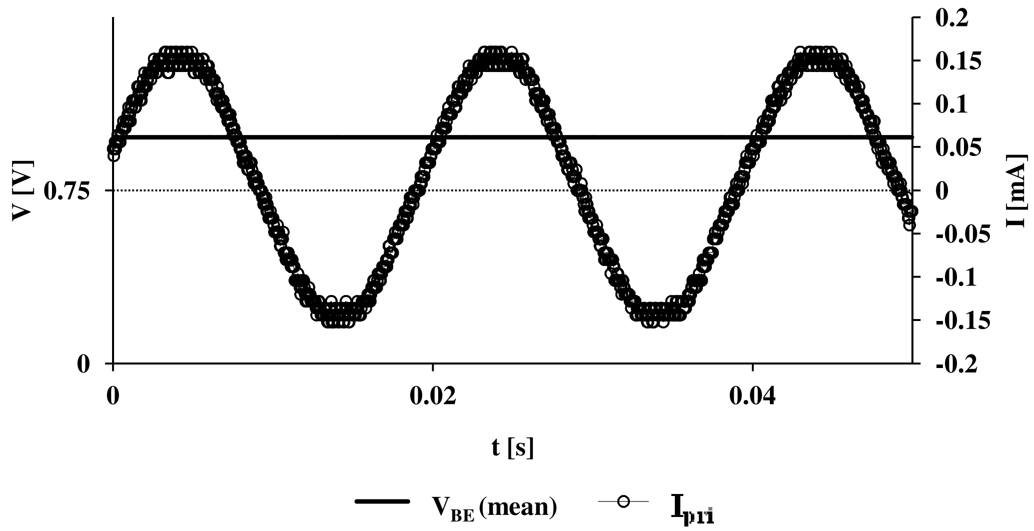


Figure A-6: Minimum conditions required for a state change.

A.4. A Switching Profile

Figure A-7 presents the switching profile obtained from an air conditioning unit and the user's behaviour is clearly evident. The x-axis presents the date-and-time values at which ach state change occurred, while the load state is presented on the y-axis.. From the switching profile it is clearly evident that the load operation coincides with the average working day. The load is switched *ON* between 08:00 and 08:30, coinciding with the occupant's arrival at the area, while the load is switched *OFF* between 16:30 and 17:15, coinciding with the occupant leaving the area.

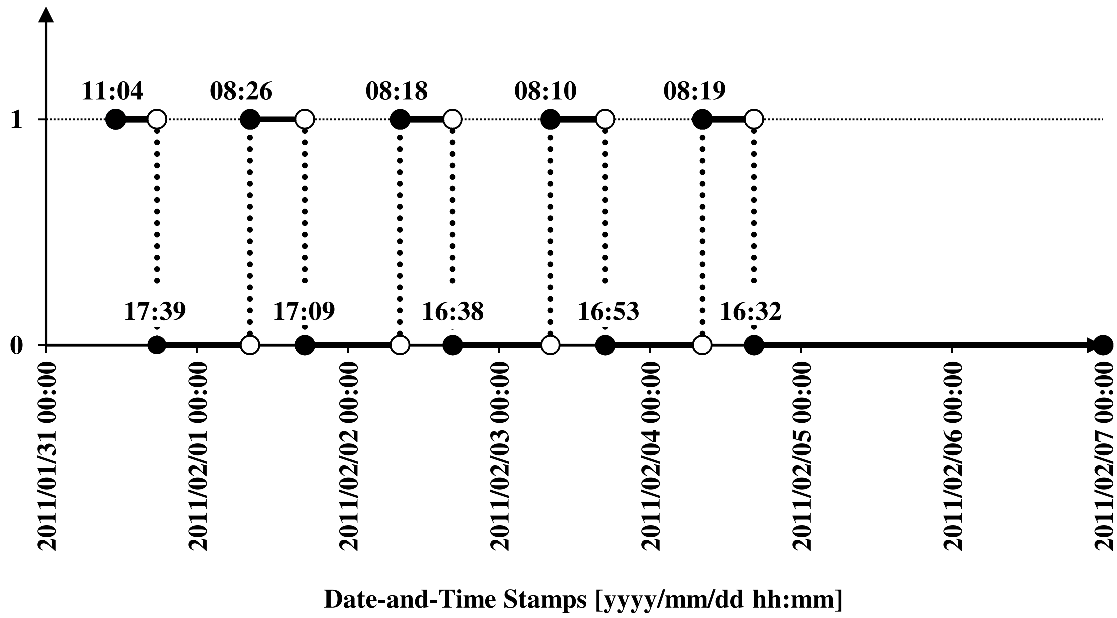


Figure A-7: Switching profile gained from an air conditioning unit.

Appendix B α-VALUES

B.1. Overview

Electrical loads do not operate at their name plate ratings due to various reasons. In this chapter the name plate ratings of lamps, monitors and personal computers are compared to the actual consumption values to determine the α-value associated with each load.

B.2. Lamps

Lamps' electrical rating varies as a function of voltage [30]. This section contains the consumption measurements for the three types of lamps: Incandescent (IL), Compact Fluorescent Lamps (CFL) and Tubular Fluorescent Lamps (TFLs). For each type of lamp three samples, from a manufacturer, was tested and the actual consumption compared to the rated value. Note that the α-values determined for the TFLs includes the ballast, as it functions as a unit.

B.2.1 Incandescent and Compact Fluorescent Lamps

The actual consumption values for both the IL and the CFL are contained in Table B-2 and Table B-3, respectively. The α-values for the various lamps are presented in Table B-1 and were calculated by adding the "*% of rated power*" at 230 V for the three samples and then averaging the total.

Table B-1: α-values for IL and CFL.

Lamp type	Rating [W]	α-value [%]
Incandescent Lamp	60	96
	100	95
Compact Fluorescent Lamp	14	90
	20	90

Table B-2: IL measurements.

Manufacturer / Model	Power Rating [W]	Sample number	% of rated power		
			at 207 V	at 230 V	at 253 V
A	60	1	82.17	96.17	111.17
		2	81.83	96.33	111.5
		3	82.67	96.67	111.83
	100	1	80.5	93.5	108.2
		2	79.9	93.5	108.3
		3	80.3	94.1	108.7
B	60	1	80	94.33	109.17
		2	79	92.5	107.17
		3	79.83	94.17	108.67
	100	1	80.1	94.1	109.1
		2	80.7	93.9	108.6
		3	81.2	94.1	108.6
C	60	1	86.33	101.33	117
		2	83.5	97.67	112.83
		3	83	96.83	111.67
	100	1	81.3	95.5	110.5
		2	82.2	95.6	110.6
		3	85.1	98.5	114.2

Table B-3: CFL measurements.

Manufacturer / Model	Power Rating [W]	Sample number	% of rated power		
			207 V	230 V	253 V
A	14	1	82.86	92.86	100.71
		2	82.86	90	107.14
		3	84.29	92.86	104.29
	20	1	83.0	92.50	105.0
		2	81.0	91.50	103.0
		3	81.50	91.50	110.50
B	14	1	85.71	92.86	106.43
		2	88.57	97.14	111.43
		3	86.42	95	108.57
C	14	1	77.14	87.86	99.29
		2	76.43	84.28	101.43
		3	72.86	80.71	95.0
	20	1	77.50	86.50	99.0
		2	81.50	84	95.0
		3	80.0	85	96.50
D	20	1	79.50	91	99.0
		2	82.50	92	100.0
		3	84.50	94	103.0

B.2.2 Tubular Fluorescent Lamps

Tubular Fluorescent Lamps (TFL) can consist of either magnetic or electronic ballast. In order to determine the variations for the three input voltages, lamps from two manufacturers were chosen and analyzed with both magnetic and electronic ballasts. The actual consumption values for both the IL and the CFL are contained in Table B-4 and Table B-5, respectively. The α-values for the various lamps are presented in Table B-6 and were calculated by adding the "*% of rated power*" at 230V for the three samples and then averaging the total.

Table B-4: TFL measurements with magnetic ballasts.

Manufacturer / Model	Ballast Type	Ballast Manufacturer	Power Rating [W]	Sample Number	% of rated power		
					at 207 V	at 230 V	at 253 V
A	Magnetic	alpha	36	1	96.39	120	147.5
				2	95.56	120.28	147.22
				3	95	119.72	147.5
			58	1	85.69	114.48	140.69
				2	91.72	118.97	145.51
				3	86.55	114.66	141.55
B	Magnetic	alpha	36	1	96.94	120.28	147.5
				2	96.11	120.83	148.61
				3	96.67	120.56	148.89
			58	1	88.62	115.34	140.51
				2	93.10	120.17	145.68
				3	87.59	115	141.03

Table B-5: TFL measurements with electronic ballasts.

Manufacturer / Model	Ballast type	Ballast manufacturer	Power Rating [W]	Sample number	% of rated power		
					at 207 V	at 230 V	at 253 V
A	Electronic	alpha	36	1	90.56	101.39	113.06
				2	88.61	99.167	110.06
				3	93.06	105.56	118.33
			58	1	85.34	95.35	105.69
				2	82.41	91.21	100.52
				3	84.83	94.48	104.66
B	Electronic	alpha	36	1	88.61	99.44	110.56
				2	90.28	98.89	110
				3	90.56	99.44	111.11
			58	1	81.55	90.517	99.83
				2	81.72	90.86	99.82
				3	83.27	92.5	102.24

Table B-6: α-values for TFL with magnetic and electronic ballasts.

Ballast Type	Rating [W]	α-value [%]
Magnetic	36	120.3
	58	116.5
Electronic	36	100.7
	58	92.5

B.3. Monitors

The computer monitors encountered during the walk through audit were Liquid Crystal Display (LCD). The actual consumption for a LCD monitors was logged, from which the α-values were computed. The actual consumption, expressed as a percentage of the name plate rating, and the estimated average consumption for these monitors is presented in Figure B-1. From Figure B-1 the α–value is taken as 85.6%.

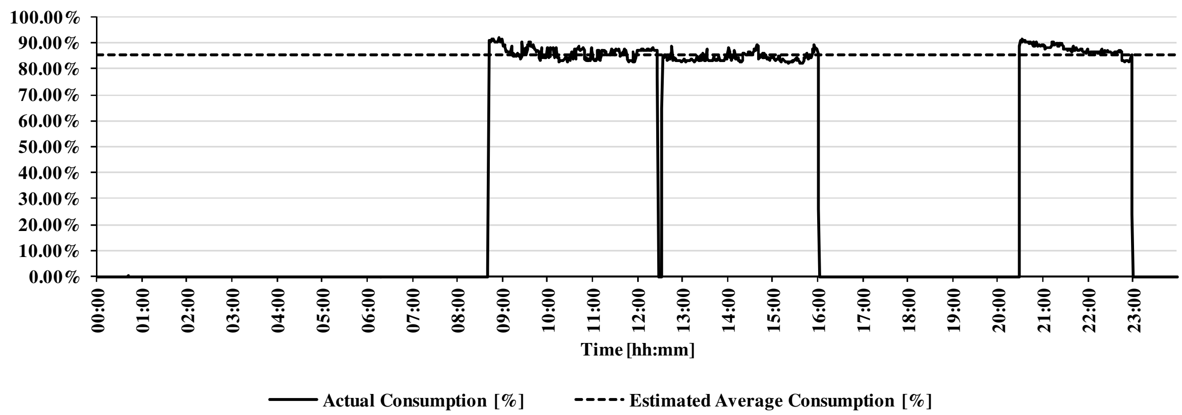


Figure B-1: Actual and averaged consumption of a LCD monitor.

B.4. Computers

The exact same process used to determine the α–value of a monitor was used to determine that of the computer tower. The actual consumption, expressed as a percentage of the name plate rating, and the estimated average consumption is presented in Figure B-2. From Figure B-2 the α-value is taken as: 24.5%.

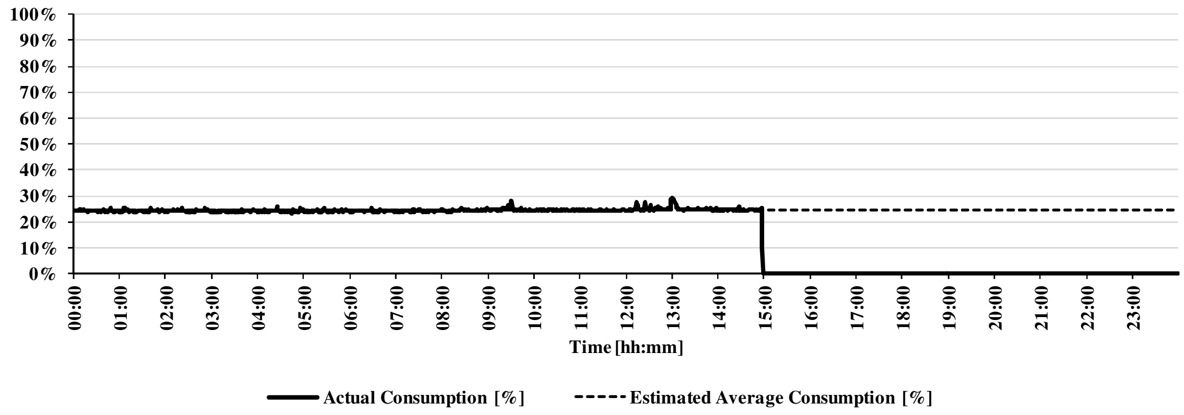


Figure B-2: Actual and estimated consumption of a computer tower.

Appendix C USAGE PROFILES

C.1. Overview

Calculating usage profiles representative of the users' behaviour required the accumulation of numerous switching profiles. These switching profiles were acquired by installing one of the two loggers presented in Figure C-1 and Figure C-2. The switching profile for the computers, monitors and air conditioning units were acquired by the logger presented in Figure C-1 and requires the loads to be plugged into the logger, which is then plugged into the wall socket.

Figure C-1: Socket logger.

Figure C-2: Through-hole logger.

Switching profiles for luminaires could have been acquired by light *ON*/*OFF* logger, but the logger could not differentiate between natural light and the light produced by the luminaires. This technicality led to insufficient data being recorded. The logger presented in Figure C-2 was used to acquire the switching profile for luminaires and are placed inside the distribution boards (DB), with the live wire routed through the hole. Note that no distinction was made between lamp and luminaire profiles as they are identical. Due to time constraints, switching profiles were obtained for one week periods for luminaires, computer and monitors. The air conditioning units were logged for numerous months, to gain insight in the air conditions dependency on ambient temperature.

Once the switching profiles were obtained, they were processed by the usage profiles applications and averaged according to the week specifications. The obtained usage profiles are discussed in the remainder of this appendix.

C.2. Air Conditioning Units

The activity of air conditioning unit depends on the ambient temperature and it is evident from Figure C-3 to Figure C-7 that air conditioning units operate less as the ambient temperature decrease (February being the end of summer and June the beginning of winter). In addition to operating less, units start operating later and end earlier as the months become cooler. The general envelope of the usage profile shows an increase from when users arrive until 12:00 after which activity decreases until 13:30, coinciding with lunch. After 13:30 activity increases and starts decreasing as occupants vacate the facility, at 16:00. The usage profile implemented in this application was determined by combining the usage profiles of August and September to best estimate the November usage profile, as hardware was limited and switching profiles could not be recorded for November. The estimated November usage profile is presented in Figure C-8.

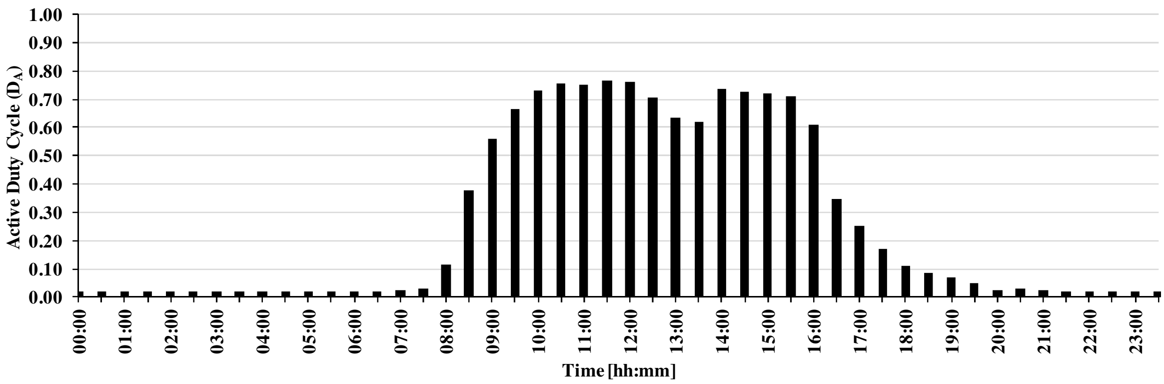


Figure C-3: The working week usage profile for the air conditioners for February.

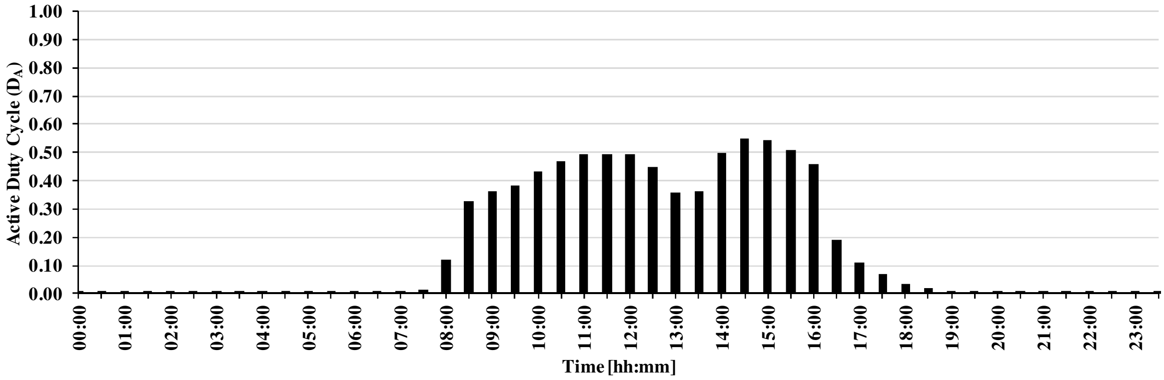


Figure C-4: The working week usage profile for the air conditioners for March.

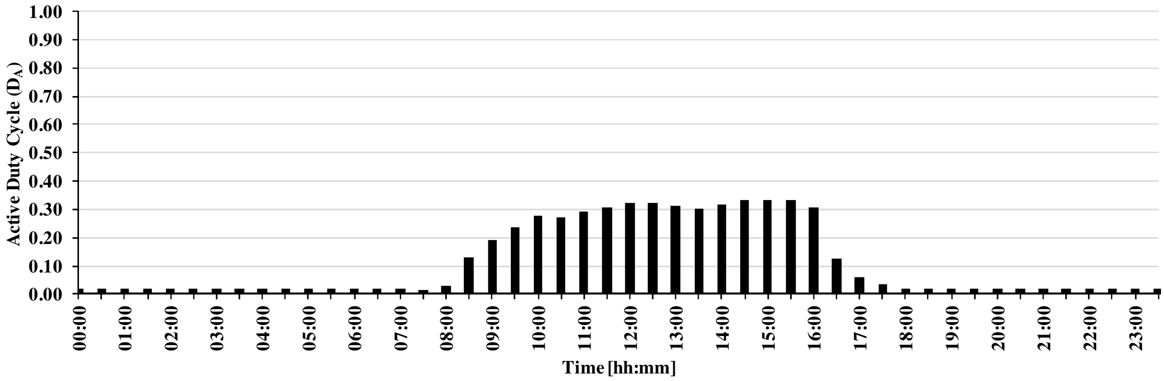


Figure C-5: The working week usage profile for the air conditioners for April.

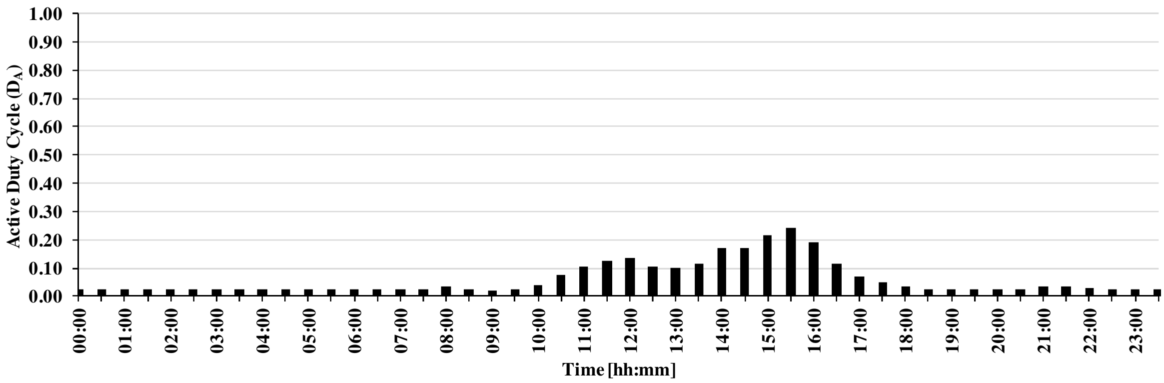


Figure C-6: The working week usage profile for the air conditioners for May.

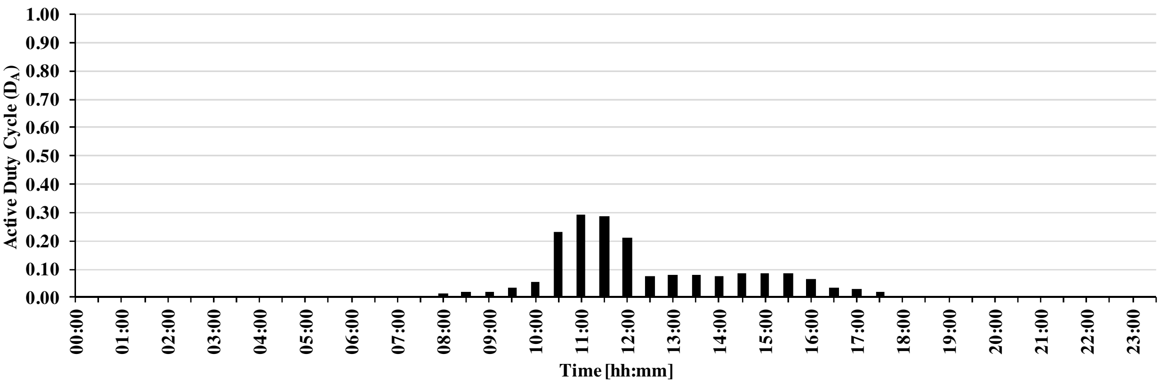


Figure C-7: The working week usage profile for the air conditioners for June.

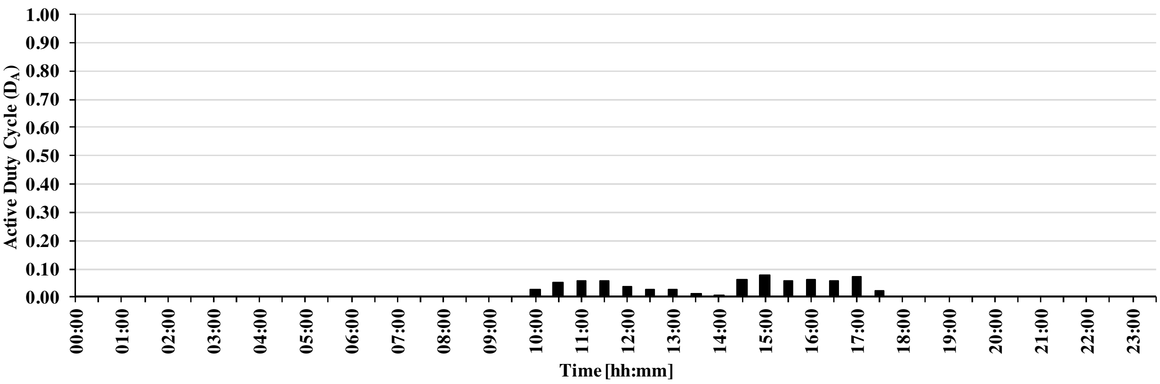


Figure C-8: The estimated working week usage profile for the air conditioners for November.

C.3. Computers

A computer can either be *OFF* or *ON*, enabling the logger to capture the actual switching profile. The usage profiles obtained from the switching profiles for the working week, Saturday and Sunday are respectively presented in Figure C-9, Figure C-10 and Figure C-11 and will be discussed in the remainder of this section.

C.3.1 Working Week

The working week shows considerable computer activity between 00:00 and 07:00, hours during which users do not occupy the areas. These activity levels are due to users refraining from switching their computer *OFF*. From 07:30 there is a steady increase in computer activity coinciding with users arriving for the day’s work. The increase is experienced until 09:30 from where the activity levels remain the same until 16:30. From 16:30 to 17:30 there is a decrease in activity coinciding with users leaving the facility. However, the 17:30

consumption level is maintained until 21:30 when there is once again a decrease in activity associated with the users leaving the facility. Note that some areas contained post-graduate student hence the high activity levels from 20:00 to 23:00 after which the activity levels between 00:00 and 07:00 are reached.

C.3.2 Saturday and Sunday

During the weekend there are some occupants using their computers, resulting in an increase in activity from 09:00 on a Saturday and 10:00 on a Sunday. The occupants leave at 18:30 on a Saturday and 14:00 on a Sunday, earlier than during the working week. The activity levels during 00:00 and 07:00 are lower than during the working week, due to some users switch their computers *OFF* over the weekend.

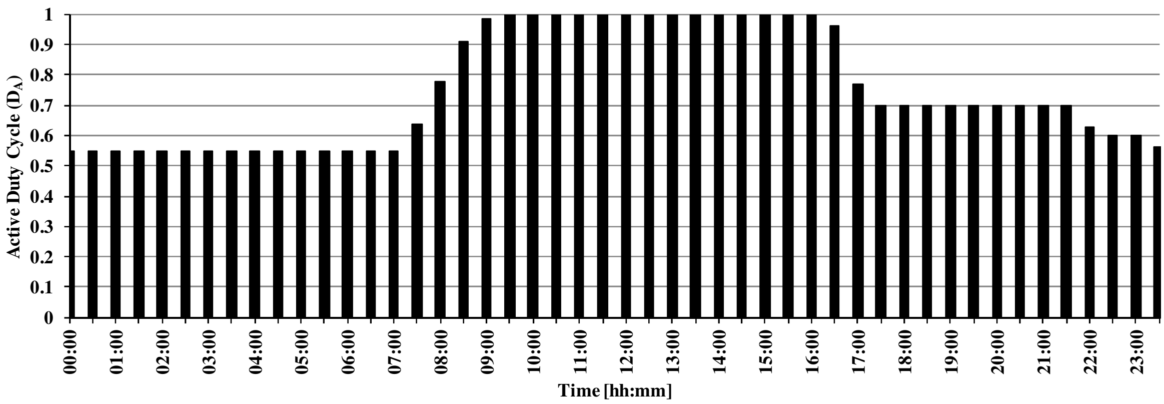


Figure C-9: The working week usage profile for computers.

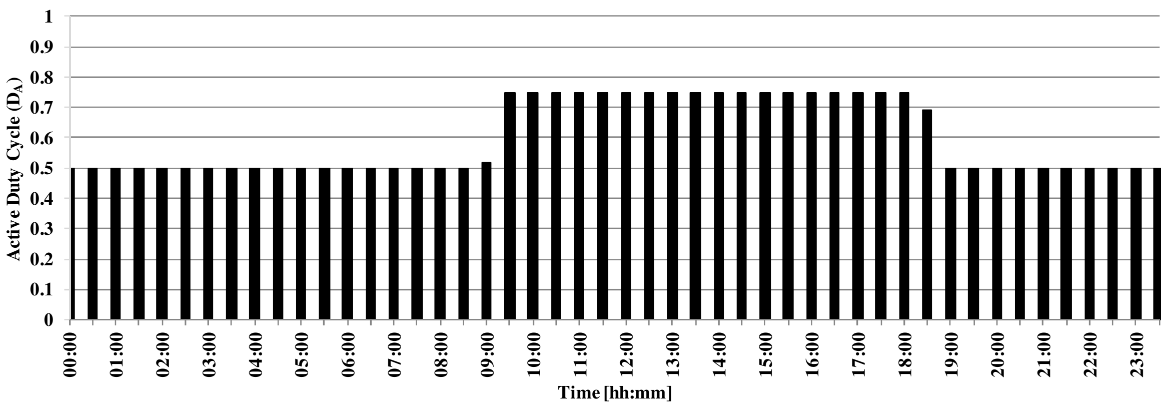


Figure C-10: The Saturday usage profiles for computers.

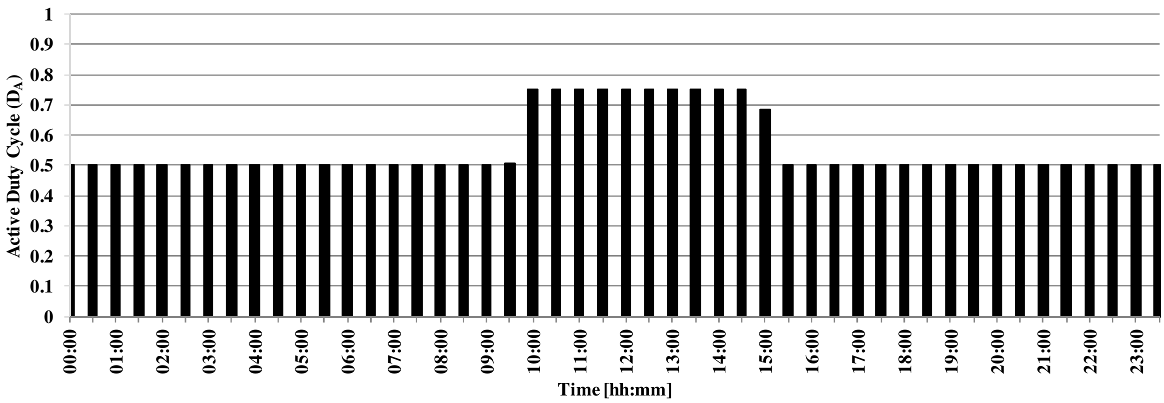


Figure C-11: The Sunday usage profile for computers.

C.4. Luminaires and Lamps

A lamp can either be *OFF* or *ON*, enabling the logger to capture the actual switching profile. The usage profiles obtained from the switching profiles for the working week, Saturday and Sunday are respectively presented in Figure C-12, Figure C-13 and Figure C-14 and will be discussed in the remainder of this section.

C.4.1 Working Week

From 00:00 to 01:00 there are lights turned *ON* which are part emergency lighting and part occupant working late. From 02:00 until the 07:00 the activity remains constant and is due to lights left *ON* during the night. From 07:30 there is an increase in the lighting activity as occupants arrive at the facility. The activity increases until 10:30 after which it decreases until 13:30. The decrease can be due to occupants taking tee around 10:30 and only not switching the lights back *ON* until after lunch. At 16:00 there is an decrease in activity as occupants start leaving the facility. The increase after 19:00 is due to occupants returning and working in the evening.

C.4.2 Saturday and Sunday

During the weekend there were some occupants at the facility resulting in activity between 19:00 and 23:00 on Saturday and between 17:00 and 19:00 on Sunday.

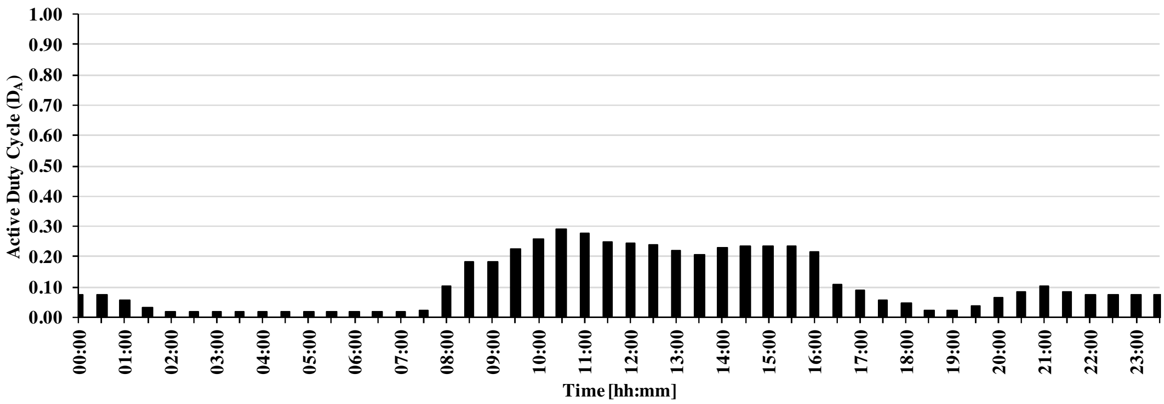


Figure C-12: The working week usage profile for luminaires and lamps.

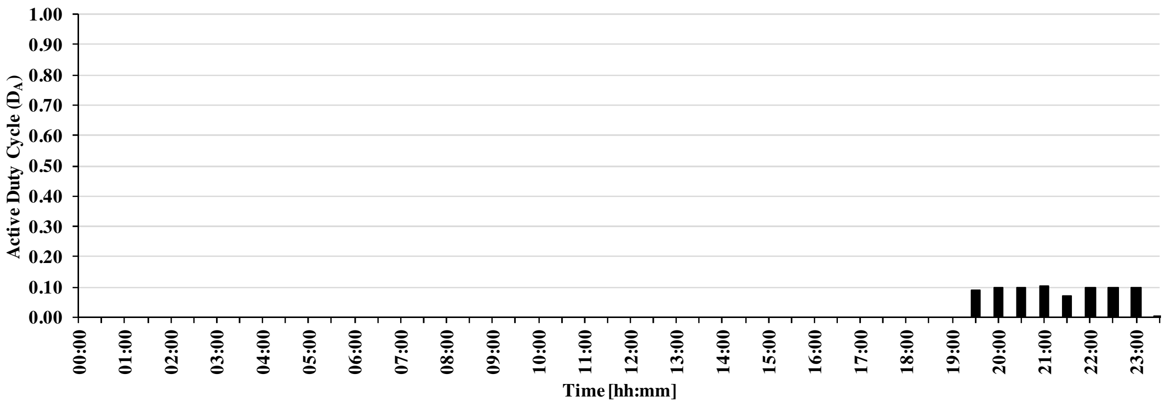


Figure C-13: The Saturday usage profile for luminaires and lamps.

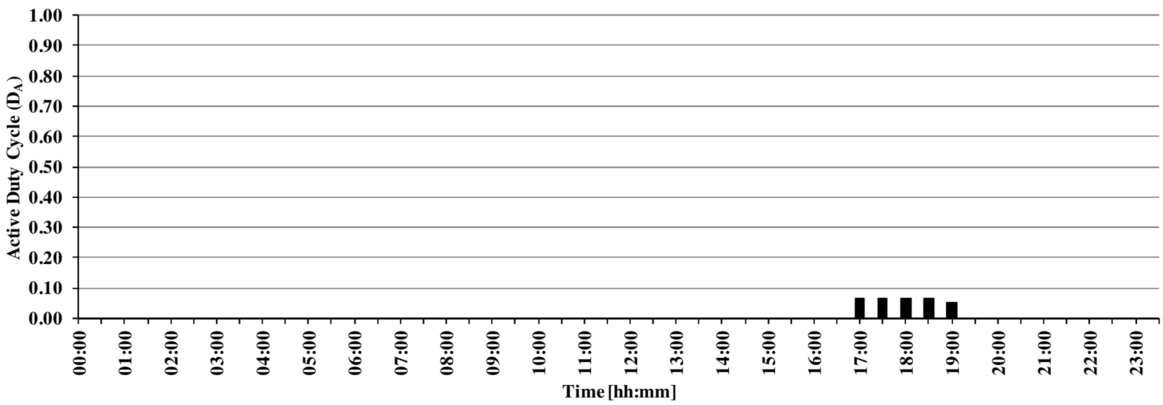


Figure C-14: The Sunday usage profile for luminaires and lamps.

C.5. Monitors

A monitor can either be *OFF*, *ON* or on screen saver. The data loggers can only accommodate two states requiring that *OFF* and screen saver be incorporated as one state. This assumption can be made as difference in power consumption, between *OFF* and screen saver, can be neglected for all practical purposes. The usage profiles obtained from the switching profiles for the working week, Saturday and Sunday are respectively presented in Figure C-15, Figure C-16 and Figure C-17 and will be discussed in the remainder of this section

C.5.1 Working Week

There is a steady increase in monitor activity from 07:00 until 09:00, coinciding with users arriving. From 10:00 to 10:30 there is a decrease in activity as it tee time and some user leave their working stations. From 11:00 there is increased activity until 13:00 when users take lunch, once again leaving their working stations. After lunch there is an increase in activity, but much less than the increase experienced after tee. From 14:30 there is a steady decrease in activity as users leave their working stations for the day.

It is interesting to note that the usage profile for the monitors does not increase to 1, due to the nature of the working environment where the monitor switches to screen saver mode after a certain period of time, when left unattended.

C.5.2 Saturday and Sunday

During the weekend there was some monitor activity, but most monitors were turned *OFF* or in screen saving mode during weekend.

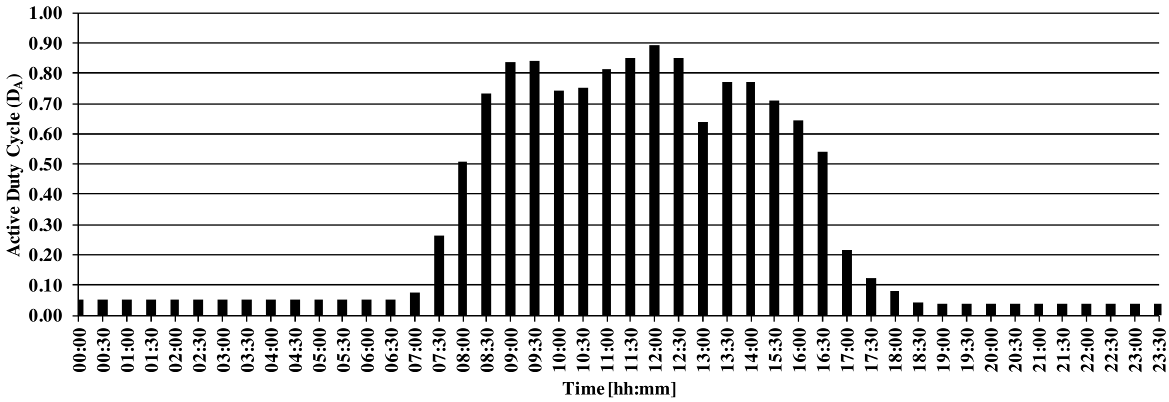


Figure C-15: The working week usage profiles for monitors.

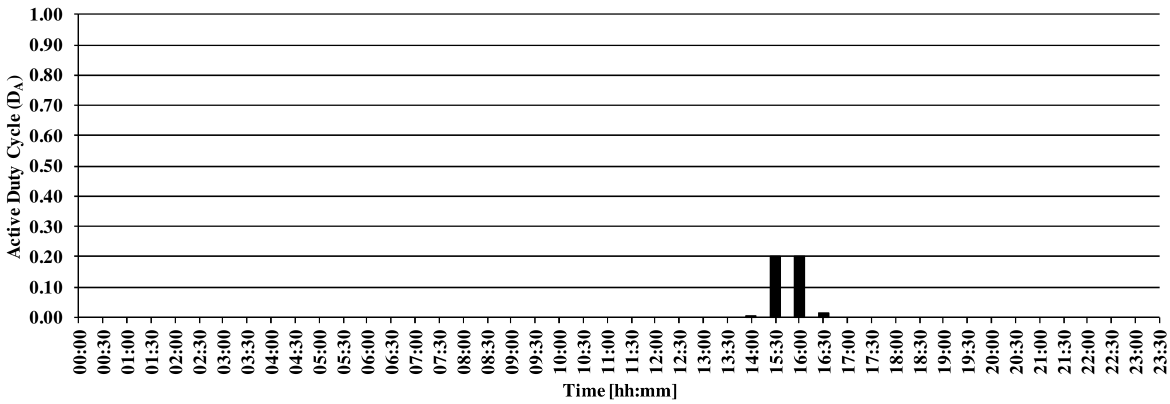


Figure C-16: The Saturday usage profiles for monitors.

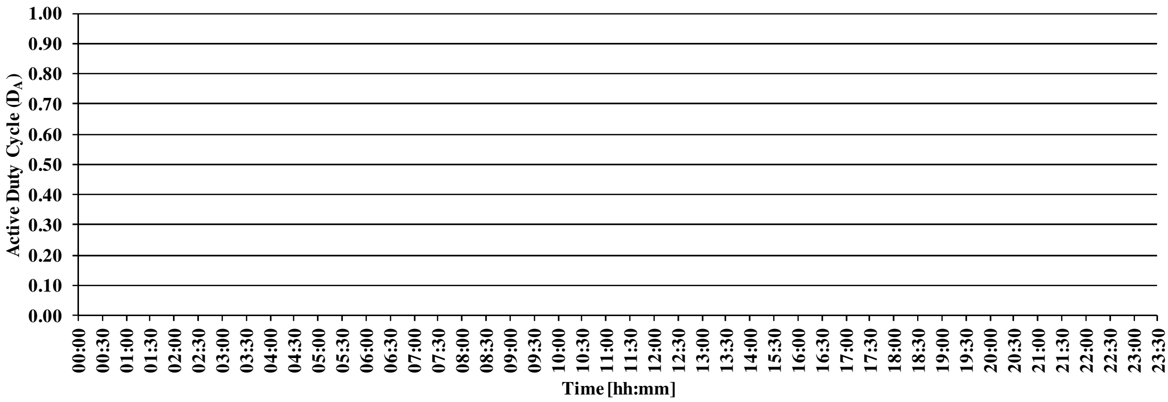


Figure C-17: The Sunday usage profiles for monitors.

C.6. Conclusion

The air conditioner usage profiles are influenced by the ambient temperature and would require the usage profiles to be update for each season. The monitor, luminaire and lamp usage profiles coincide with user behaviour while computer see an increase in consumption when occupants arrive, but also show significant consumption levels during the evening due to occupants not switching their computers *OFF* when they leave the facility.

Appendix D DATABASE DESIGN

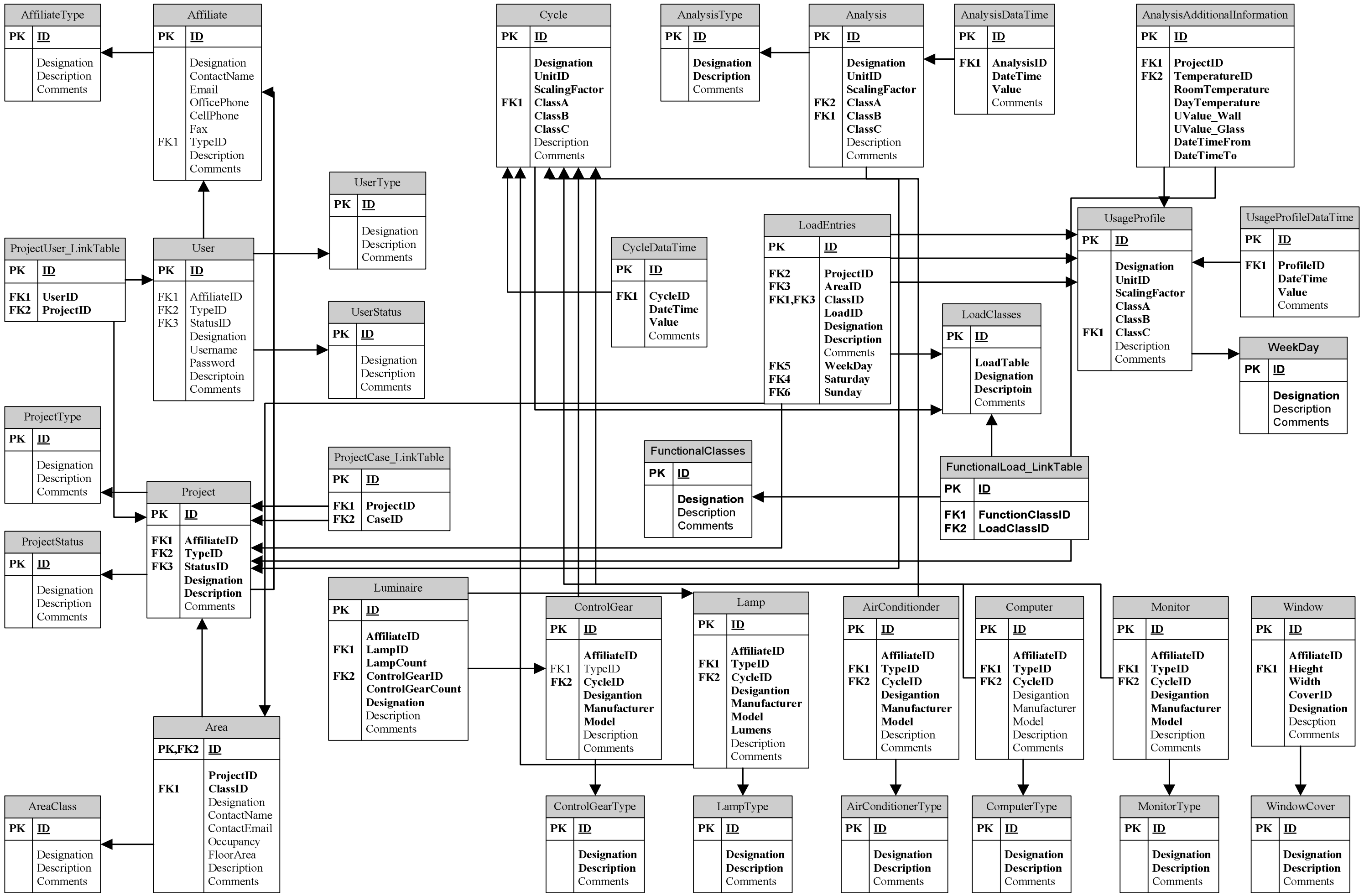


Figure D-1: The complete database design.

Appendix E SOFTWARE DESIGN

This appendix presents the design of the various OOP classes according to the sections identified in Chapter 3. Two types of UML diagrams were used to present the OOP class: a class diagram and an activity diagram. The class diagrams were used to present the interrelationships, the operations and the attributes of the classes, while the activity diagrams were used to indicate the flow within a class.

All the classes have two attributes in common: a database connection and a user. The database connection establishes the connection to the required database while the user attribute contains the user information used to set user related variables such as navigation and project access. Figure E-1 presents the user class, *TUser*, together with the permissions class, *TPermissions*.

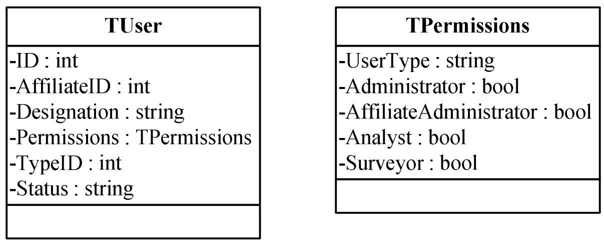


Figure E-1: *TUser* and *TPermissions.*

TUser consists of attributes for the the user's ID, the affiliates ID, the designation, the permissions, the user type and the status, while *TPermissions* contains the user type information.

In addition to the UML diagram the executed SQL-queries, where applicable, will be provided. The query execution is done by making use of Delphi's dbExpres component library and requires a SQLDataSet, DataSetProvider, ClientDataSet and a DataSource.

The ClientDataSet points to a DataSetProvider through its ProviderName property, and the DataSetProvider refers to the SQLDataSet through its DataSet property. When you set the

ClientDataSet's Active property to *true* or invoke its Open method, the ClientDataSet makes a data packet request from the DataSetProvider. This provider then opens the SQLDataset to which it points, goes to the first record, and then scans through the records until it reaches the end of the file. With each record it encounters the DataSetProvider encodes the data into a variant array. This variant array is sometimes referred to as the *data packet*. When the DataSetProvider is done scanning the records, it closes the dataset to which it points, and then passes the data packet to the ClientDataSet. Once the data packet has been retrieved, it can be assigned to a Datasource, a data access component enabling the display of the requested data packet. As these components are used throughout the application, a class was created consolidating all these components into one class. The class designed was *TDisplaySource* and consists of a SQLDataSet, DataSetProvider, ClientDataSet and a DataSource, enabling the designer to easily insert, update, refresh, execute queries and display results.

E.1. TLogIn

The window associated with *TLogin* is presented in Figure E-2. The associated activity diagram is presented in Figure E-3.

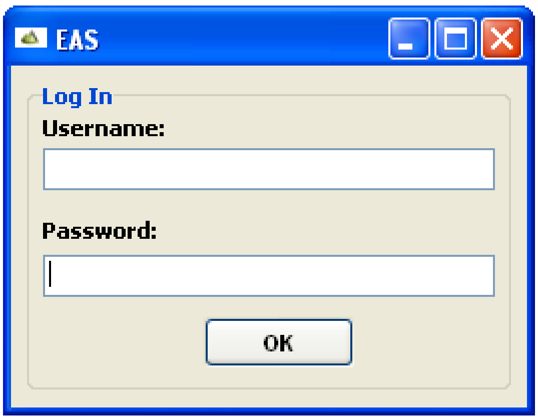


Figure E-2: The login window presented to the Users.

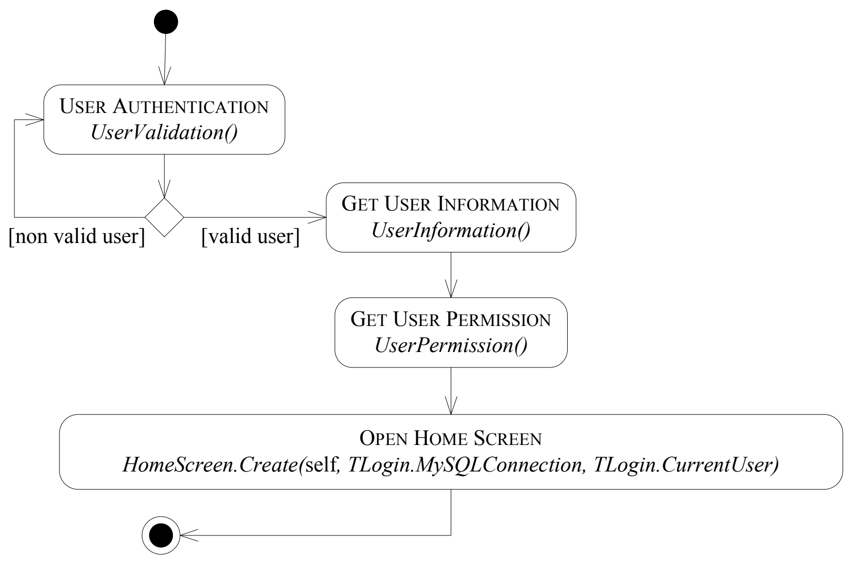


Figure E-3: Activity diagram of *TLogIn*.

After the user presents the username and password, it is authenticated. Depending on the result, the user is either informed that the information is incorrect or the user's information is retrieved from the *User* table. After the information has been retrieved, the permissions are set followed by the main window, *Home*.

function TLogin.UserValidation() :**String**;

The user's *username* is obtained as an input variable, which is then used to generate the query in Listing E-1.

SELECT	A.ID, A.AffiliateID, A.Designation, A.Username, A.Password, A.TypeID, A.Description, A.Comments, B.Designation B.UserStatus
FROM	User A
LEFT JOIN	user_status B ON A.StatusID=B.ID
WHERE	A.Username = *username*

Listing E-1: The query to retrieve the user's information based on the *username*

The result gained from the query in Listing E-1 is then assigned to *TLogin.DisplaySource*, which grants the designer access to the data packet retrieved.

procedure UserInformation();

Assigns *TLogin.CurrentUser* attributes from *TLogin. DisplaySource*.

procedure UserPermission();

The user's permissions are set by assigning the result of the query in Listing E-2 to *TLogin.CurrentUser.Permissions*.

```
'SELECT    *
FROM       UserType
 WHERE     ID = TLogin.CurrentUser.TypeID
```

Listing E-2: Query to retrieve the user's permissions.

constructor THomeScreen.Create(self, *TLogin.MySQLConnection*, *TLogin.CurrentUser*);

After the user has been validated and the various attributes set, an instance of the *THome* is created.

E.2. THome

The window associated with *THome* is presented in Figure E-4 and presents the user with their username and user group.

Figure E-4: The main window presented to the users.

The four tabs contained in the navigation bar at the top of the window allow for the navigation to the various sections and are enabled depending on the user's permissions. A summary of the navigation tabs, as well as the various sections and users to which they provide access, is presented in Table E-1.

Table E-1: Summary of the navigation tabs.

Navigation Tab	Usre Type	Description
File	Affilaite Administrator	Allows affilaite administrators to assign new user to projects
Projects	Affilaite Administrator Surveyor	Surveyor can access their projects and complete surveys on the available areas. Affilate administrators can complete surveys but also conduct analysis on projects as required.
Manage Database	Administrator	Allows administrators to access the inventory and adminsitration sections of the application.
Log Out	All	Allows a current user to sign out.

The activity diagram of *THome* is presented in Figure E-5. After the initialisation of an instance the user can navigate based on their assigned permissions, as presented in the activity diagram.

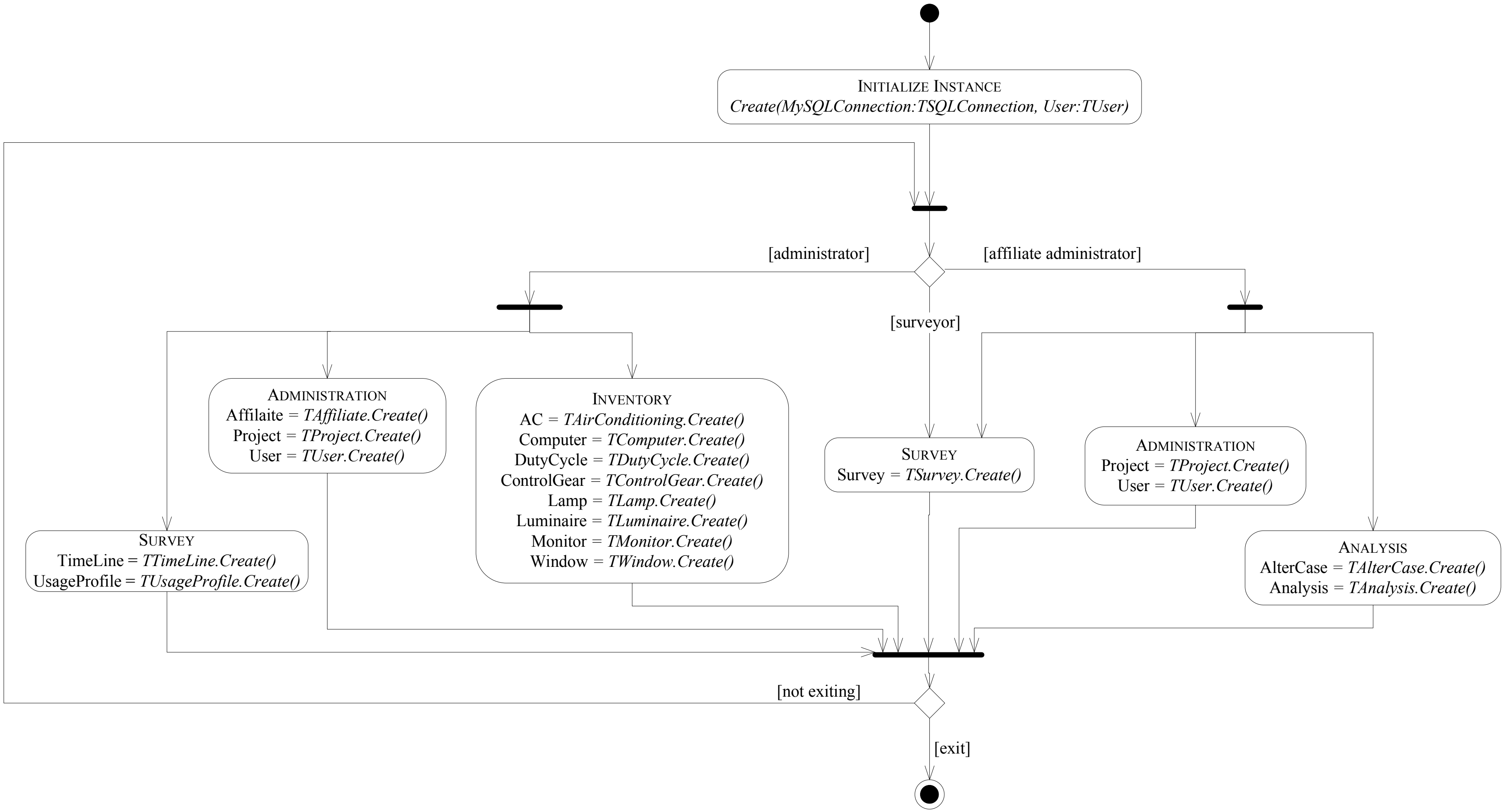


Figure E-5: Activity diagram of *THome*

E.3. Administration and Inventory

The administration and the inventory sections requires windows to assist the administrators in populating the fields of various tables. The activity diagram is presented in Figure E-6.

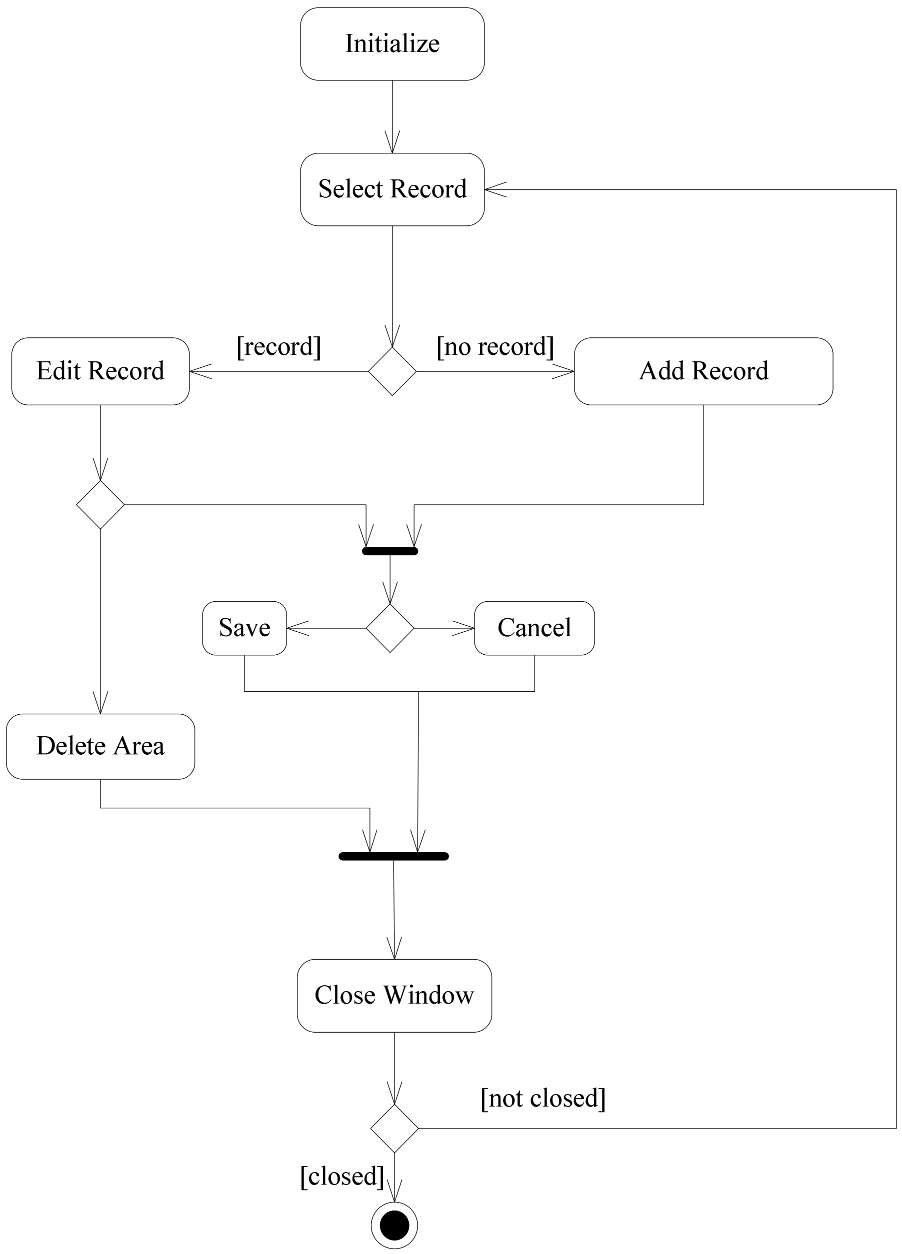


Figure E-6: Activity diagram of the generic window required to populate fields contained in various tables.

After an instance has been initialized the user is presented with the records available. Once the records are presented, the user can select a record to alter of add new record. If a record is selected, it can either be altered and save or deleted. If a new record is to be added, the associated fields will be required after which the user can decide to commit the new record to the database. If the users decides to cancel current activity for whatever reason, no changes are committed.

E.4. Analysis

The analysis functional group contains two classes e.g. *TAlterCase* and *TAnalysis*, both which will be discussed in this section.

E.4.1 TAlterCase

The window used to alter cases is presented in Figure E-7, with the accompanying activity diagram presented in Figure E-8.

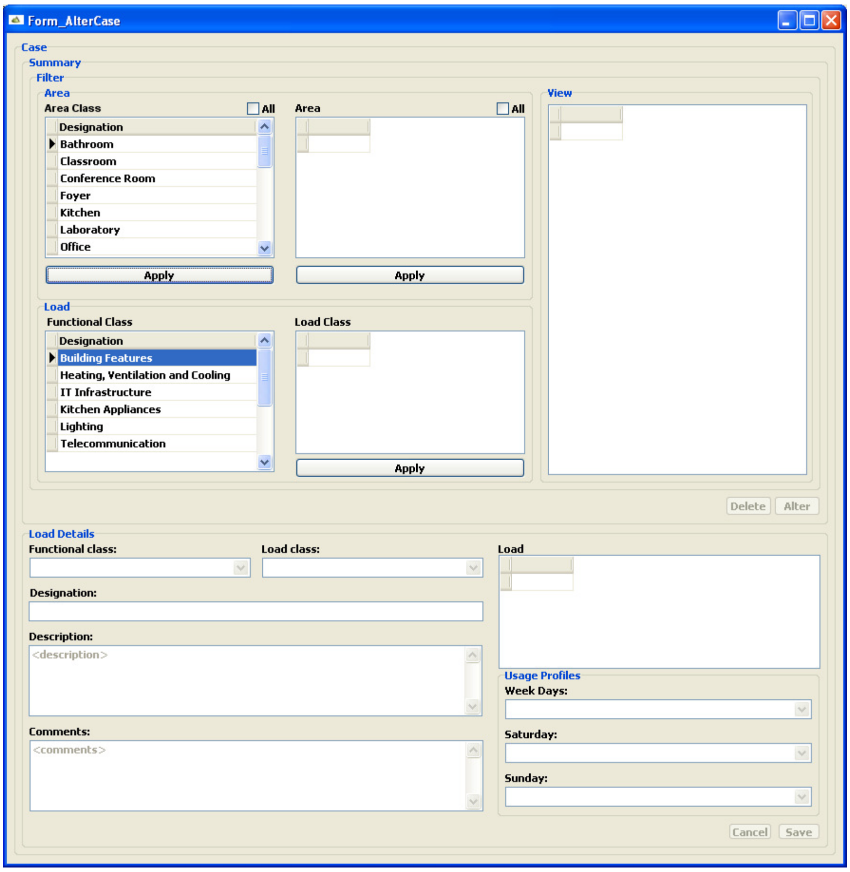


Figure E-7: Window used to alter case.

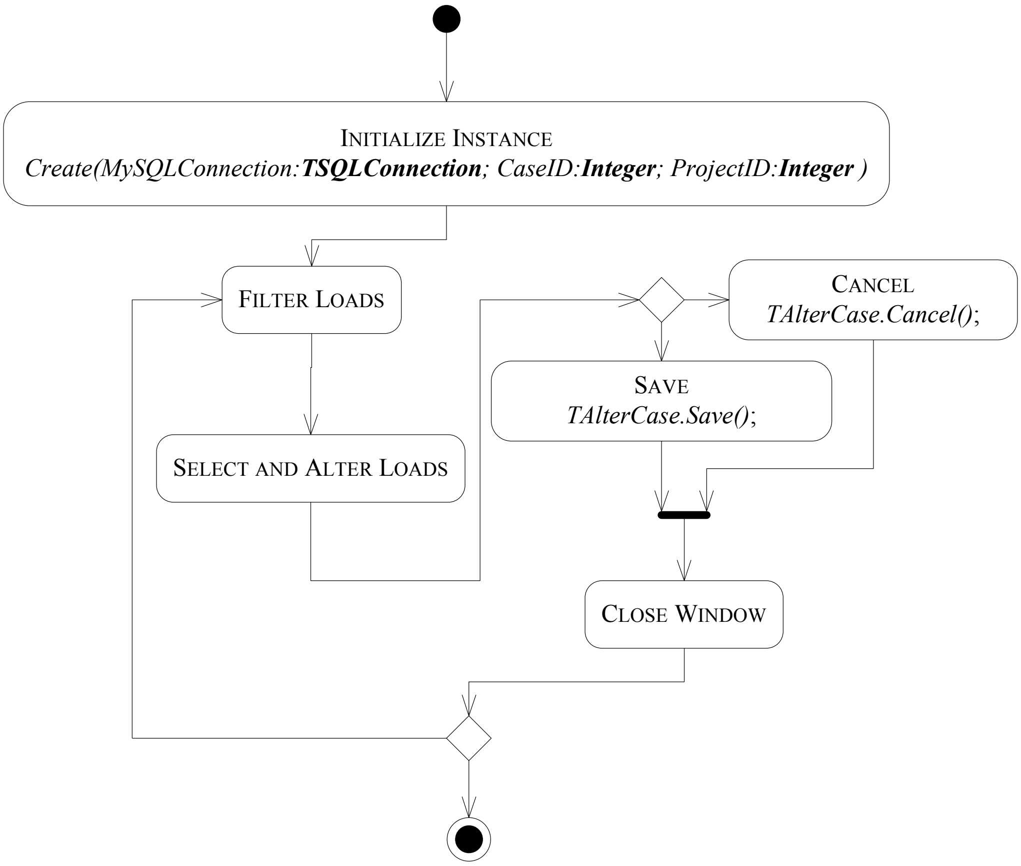


Figure E-8: Activity diagram for *TAlterCase*

After an instance has been initialized the user can filter the entries based on the area class, the area, the functional class and the load class. The obtained loads can then be selected and altered as the user pleases. After the changes have been made the user can decided to commit the changes to the database or to ignore. After completing the alteration process the user can exit or alter additional loads.

- **Initialize**

constructor TAlterCase.Create(*MySQLConnection:**TSQLConnection**; CaseID:**Integer**; ProjectID:**Integer***);

During the initialisation a project and case identifier, *TAlterCase.ProjectID* and *TAlterCase.CaseID*, is set to *CaseID* and *ProjectID*, respectively.

Altering cases requires the entries to be filtered. Loads are assigned to areas and can be filtered based on its functional and load class. The options available for the area class and functional class are gained by the queries in Listing E-3 and Listing E-4, respectively. These results, which are presented to the user, are assigned to two DisplaySource instances: *TAlterCase.AreaClass* and *TAlterCase.FunctionalClass*

Listing E-3: The query executed to obtain the area class that can be assigned to the areas

SELECT	*
FROM	*AreaClass*
WHERE	Designation<> - ALL -
ORDER BY	Designation

Listing E-4: Query executed to obtain the functional class options

SELECT	*
FROM	*FunctionalClass*
WHERE	Designation <> - ALL -
ORDER BY	Designation

- **Filter Loads**

The filtering of the loads is to be done as presented in the activity diagram in Figure E-9. The user selects an area class from which the available areas are determined by the query presented in Listing E-5.

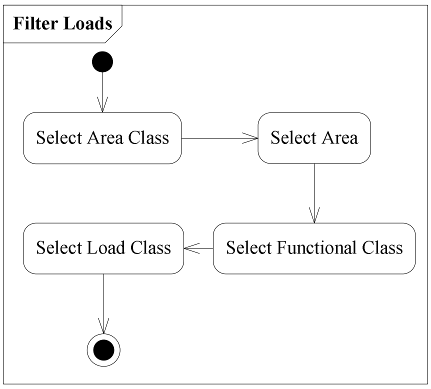


Figure E-9: The activity diagram implemented for filter loads.

The available areas, dependant on the area classes, are determined by the query in Listing E-5.

Listing E-5: Query acquiring the areas of which the loads are to be altered.

QueryID	= A query containing all the function class ID’s
SELECT	C.ID, A.ProjectID, A.Designation
FROM	Area A
LEFT JOIN	Project_Case_Link B ON B.CaseID = A.ProjectID
LEFT JOIN	Area C ON C.ProjectID = B.ProjectID
WHERE	*QueryID* AND (A.Designation=C.Designation) AND (A.ProjectID = CaseID)

With the areas chosen, the functional classes can be selected. The load classes, relevant to the functional classes, are determined by executing the query in Listing E-6. The result obtained is assigned to *TAlterCase.LoadClass.*

Listing E-6: Query required to obtain load classes.

SELECT	A.ID, A.Designation, A.TableRef
FROM	LoadClasses A
LEFT JOIN	FC_LC_Link B ON A.ID=B.LoadClassesID
LEFT JOIN	FunctionalClasses C ON B.FunctionalClassesID=C.ID
WHERE	C.ID = *TAlterCase.FunctionalClassSummary.FieldByName('ID').AsInteger*
ORDER BY	Designation

With the required load class selected, the relevant loads are determined by the query in Listing E-7 and the result is assigned to *TAlterCase.Grid*.

Listing E-7: Query to obtain the loads determined by the filtering conditions.

AreaQuery	=	contains the ID's of all the selected areas.
LCQuery	=	(LoadClassesID = *LoadClassSummary.DataSet.FieldByName('ID').AsString*)
SELECT	*	
FROM	LoadEntries	
WHERE	*LCQuery* AND *AreaQuery* AND (ProjectID = CaseID)	

- **Select and Alter Loads**

The user is presented with the loads which can be altered. The alterations currently available are load and usage profile replacements, enabling users to simulate various scenarios. Once the user has made alterations, the changes can be disregarded or committed to the database.

function TAlterCase.Save ();

TAlterCase.Grd is updated and refreshed, displaying the new/altered record to the user.

function TAlterCase.Cancel();

The proposed changes are ignored and the user is presented with the original data.

E.4.2 TAnalysis

TAnalysis enables users to analyse cases and save the results to the tables in the database. The window used to analyse cases is presented in Figure E-10, with the accompanying activity diagram presented in Figure E-11.

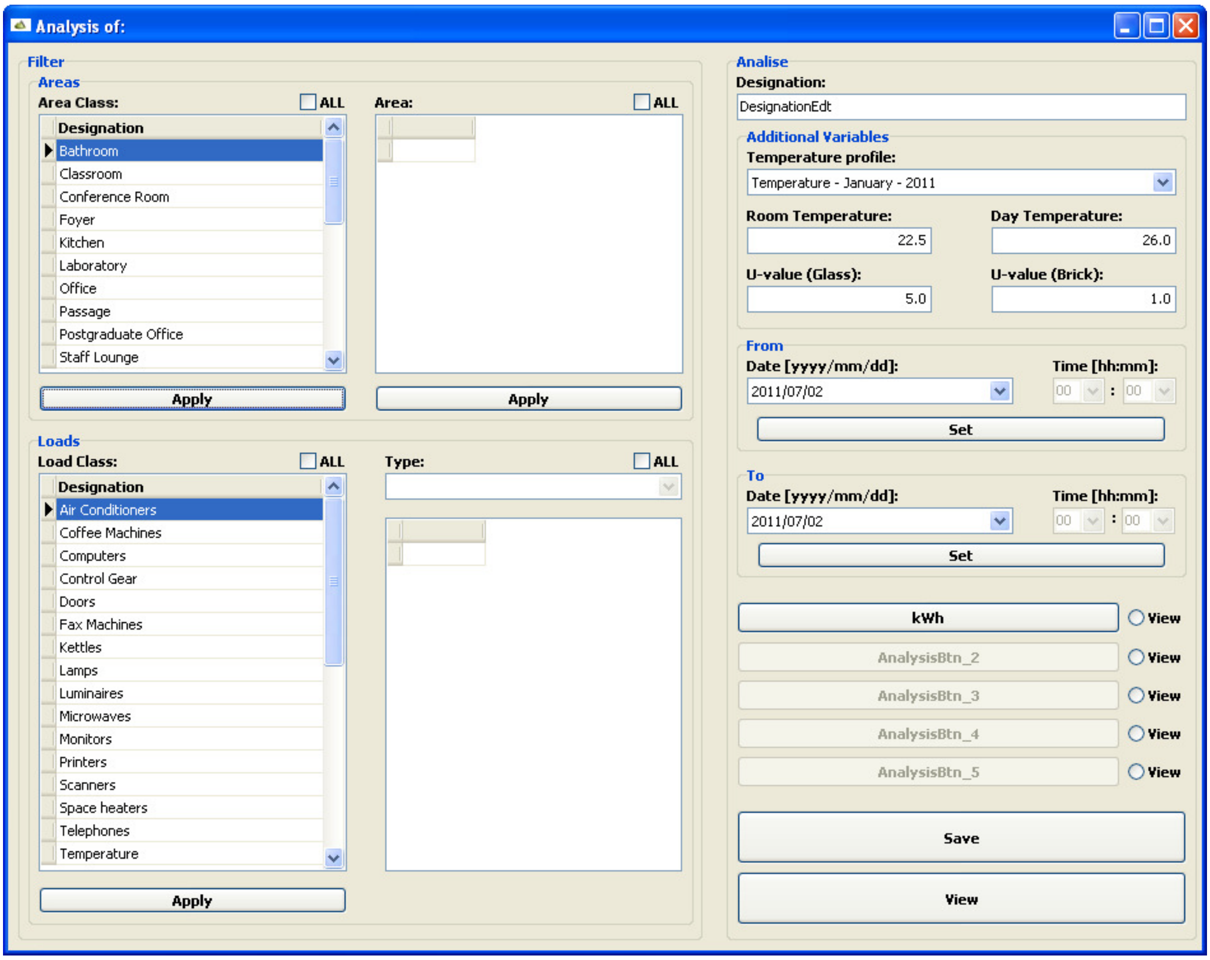


Figure E-10: Window used to analyze case.

After the initialisation of an instance, the user is presented with the exact load filter used in *TAlterCase*, after which the user has to set additional parameters to enable the completions of the analysis. Once the analysis is completed and the results are stored to the database, it results can be viewed.

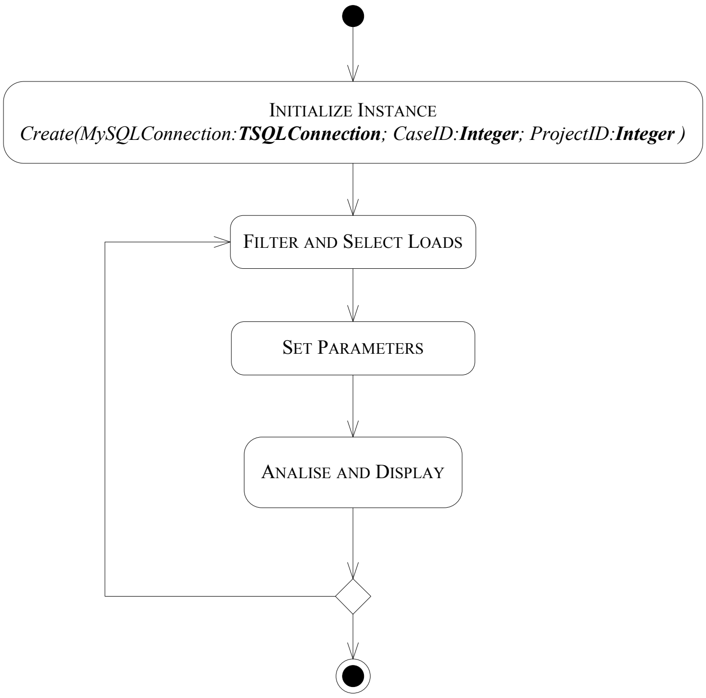


Figure E-11: Activity diagram for *TAnalysis.*

- **Initialize**

constructor TAnalysis.Create(*MySQLConnection:**TSQLConnection**; CaseID:**Integer**; ProjectID:**Integer***);

Selecting the various loads requires the entries to be filtered. The same filtering fields, used in TAlterCase, are used to filter the areas. The result gained from Listing E-3 is assigned to *TAnalise.AreaClass*. Load filtering is done by load classes selection, with the results gained from Listing E-8 being assigned to *TAnalysis.LoadClass*.

Listing E-8: Query to obtain load classes used to filter loads.

```
SELECT      *
FROM        LoadClasses
WHERE       (Designation <> - ALL -) AND (Designation <> - NONE -)
ORDER BY    Designation
```

In addition to the area classes and the load classes being set, the temperature profiles are also assigned. The queries to obtain this profile are presented in Listing E-9 and the result obtained is assigned to *TAnalysis.TemperatureProfile*.

Listing E-9: Query to obtain the temperature profiles.

```
SELECT      A.ID, A.Designation
FROM        UsageProfileInformation A
LEFT JOIN   LoadClasses B ON A.ClassB=B.ID
WHERE       B.Designation = Temperature
```

After the filter options and the temperature profiles have been set, the database is checked for previous analysis with the query in

Listing E-10: Query to obtain previous analysis.

```
SELECT      *
FROM        AnalysisProfileInformation
WHERE       ClassA = CaseID
```

- **Filter and Select Loads**

The available areas, dependant on the area classes, are determined by the query in Listing E-5 and the result gained is assigned to *TAnalysis.Areas*.

With the required area and load class selected, the relevant loads are determined by executing the query in Listing E-7; the result is assigned to *TAnalysis.Loads.*

- **Set Parameters**

In addition to selecting the loads to be included in the analysis, the user must provide the temperature profile, the average room temperature maintained in the areas, the average day temperature applicable as well as the u-values for both the glass and the brick surfaces. The complete analysis is done for a certain period in time; the beginning and end dates are also to be specified by the user.

- **Analyse and Display**

The parameters provided are combined with the loads and their assigned usage profiles to calculate the consumption profiles. The profiles created can then be saved to the database and displayed to the user.

E.5. Survey

Two classes are associated with the survey functional group e.g. *TSurvey*, and *TUsageProfile*. These classes will be discussed in the remainder of this section.

E.5.1 TSurvey

TSurvey enables users to add area and assign loads to the various areas. The window used to complete load surveys is presented in Figure E-1011, with the accompanying activity diagram presented in Figure E-11

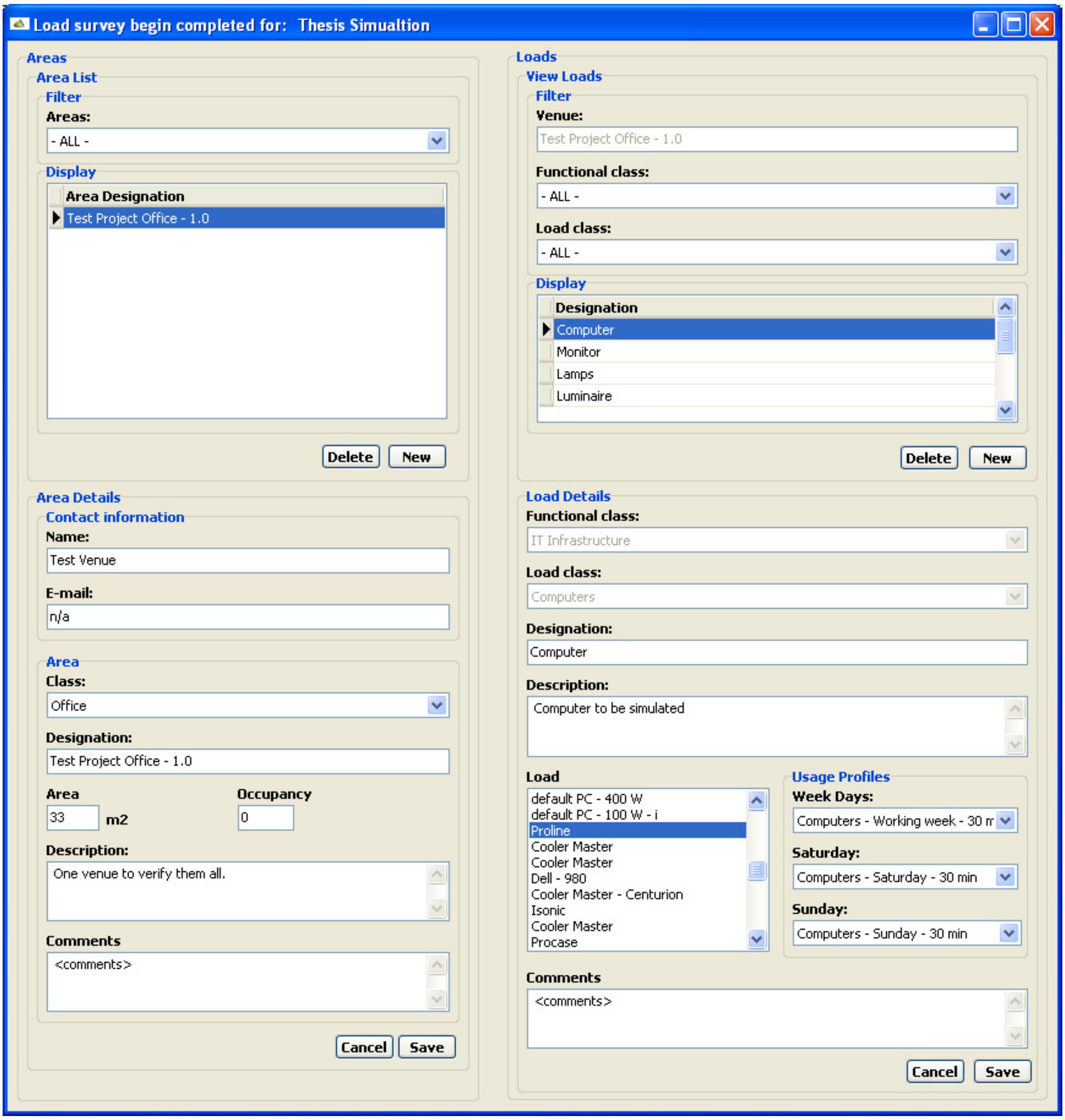


Figure E-12: Window Used to complete load survey.

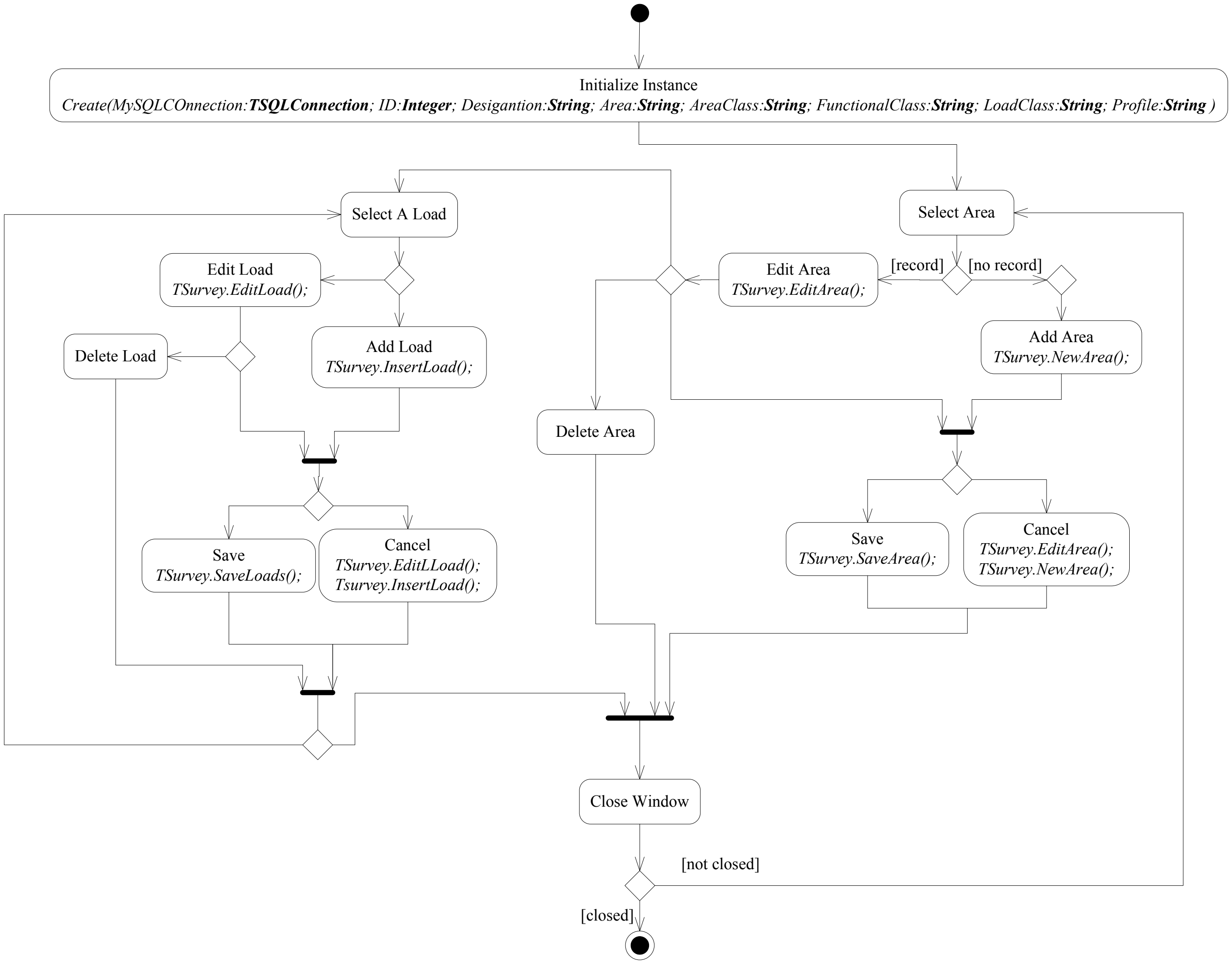


Figure E-13: Activity diagram of *TSurvey*

After The class is initialized, the user has the option of selecting an existing area or define a new area. A selected area can be altered or removed. In addition to the area related functionality, loads can be added, altered or removed from an area. After the alterations are completed the user has the option of committing the changes to the database.

- **Initialize**

constructor TSurvey.Create(*MySQLCOnnection:**TSQLConnection**; ID:**Integer**; Designantion:**String**; Area:**String**; AreaClass:**String**; FunctionalClass:**String**; LoadClass:**String**; Profile:**String***);

The project, for which the survey is being completed, is identified by *TSurvey.PROJECTID* and is set to *ID*, the unique identifier of the current project. The unique name of the project, *TSurvey.PROJECTDESIGNATION* is set to *Designation*, and is displayed as the form title.

The available options for the area classes are set by assigning the result of the query in Listing E-11 and Listing E-3 to *TSurvey.AareaClass* and *TSurvey. AareaClass_Details*, respectively. *TSurvey. AareaClass* provides the filtering options for the areas, while *TSurvey. AareaClass_Details* provides the area class options in the details section, used when adding/editing a new venue.

Listing E-11: The query executed to obtain the area classes, on which the area filtering is done.

```
SELECT      *
FROM        AreaClass
ORDER BY    Designation
```

After the area filtering options are assigned to *TSurvey.AreaClass*, *TSurvey.DisplayAreasInGrid()* is executed, containing the query in Listing E-12. The result gained from this query is assigned to *TSurvey.AreaDataSource*, which is displayed to the user.

Listing E-12: The query executed to obtain the required areas.

```
ID      =       TSurvey.ACDataSource .FieldByName('ID').AsInteger;
IF      ID <> 0         THEN
        SELECT          *
        FROM            Area
        WHERE           (AreaClassID = ID) AND (ProjectID = TSurvey.fPROJECTID)
ELSE
        SELECT          *
        FROM            Area
        WHERE            ProjectID = TSurvey.fPROJECTID
```

In addition to the area class options being assigned; two additional filters are setup: functional class (FC) and load class (LC). These filters are applicable to the load section of the survey form and assist in displaying the loads associated with a certain area. The query to obtain the functional classes is presented in Listing E-13 with the result being assigned to *TSurvey.FunctionalClass*. The load class query is presented in Listing E-14, with the result being assigned to *TSurvey.LoadClass*. Take note that the load class is dependent on the chosen functional class and refreshes after every functional class changes.

Listing E-13: Functional class query.

```
SELECT      *
FROM        FunctionalClass
 ORDER BY   Designation
```

Listing E-14: Load Class Query.

```
FCLookUp    =     FunctionalClasse.ClientDataSet.FieldByName('ID').AsInteger;
IF    TSurvey.FunctioanlClass.ClientDataSet.FieldByName('Designation').AsString <> '- ALL -'
      SELECT      A.ID, A.Designation
      FROM        LoadClass A
      LEFT JOIN   FC_LC_Link B ON A.ID = B.LoadClassesID
      LEFT JOIN    FunctionalClass C ON B.FunctionalClassesID = C.ID
      WHERE        (C.ID = FCLookUp) OR (A.Designation = - ALL -)
      ORDER BY    Designation
ELSE
      SELECT      *
      FROM        LoadClass
       ORDER BY   Designation
```

During the load assignment, the functional class and load class fields both need to be selected, to provide the set of available loads and usage profiles. The query executed for the functional class options is presented in Listing E-4, of which the result is assigned to *TSurvey.FunctionalClass_Details.*

The load class options are dependent on the function class selected and changes as the functional class changes. The query to retrieve the load classes is presented in Listing E-15 and the result is assigned to *TSurvey.LoadClass_Details*.

Listing E-15: Load class query for details section.

SELECT	A.ID, A.Designation, A.TableRef
FROM	*LoadClass* A
LEFT JOIN	FC_LC_Link B ON A.ID=B.LoadClassesID
LEFT JOIN	*FunctionalClass* C ON B.FunctionalClassesID=C.ID
WHERE	C.ID = *FCDataSource_Details.FieldByName('ID').AsInteger*
ORDER BY	Designation

After the selection of a load class, the relevant loads are obtained based on the functional class and load class and assigned to *TSurvey.LoadDisplay* to present to the user. The query is presented in Listing E-16, with *AreaID*, *FCLookUp* and *LCLookUp* presenting the ID of the chosen area, function class and load class, respectively. *FilterQuery* is generated by the filter conditions, and varies as the user changes the area, the functional class and the load class. To incorporate this dynamic behaviour, *AreaQuery*, *FCQuery* and *LCQuery* are used to build *FilterQuery*, based on certain conditions.

Listing E-16: The query to display the surveyed loads related to an area.

```
AreaID       =      Area.ClientDataSet.FieldByName('ID').AsInteger;

FCLookUp     =      FunctionalClass.ClientDataSet.FieldByName('ID') AsInteger;

LCLookUp     =      LoadClass.ClientDataSet.FieldByName('ID').AsInteger;


SELECT       A.ID, A.Designation, E.Designation AS ProfileName, C.FunctionalClassesID,
             C.LoadClassesID, B.TableRef

FROM         load_entries A  '

LEFT JOIN    load_classes B ON A.LoadClassesID = B.ID

LEFT JOIN    functionalclasses_loadclasses_link C ON B.ID = C.LoadClassesID

LEFT JOIN    functional_classes  D ON C.FunctionalClassesID = D.ID

LEFT JOIN    profile E ON A.ProfileID = E.ID

WHERE         (ProjectID = fPROJECTID) AND FilterQuery


AreaQuery    =      (A.AreaID = AreaID);

FCQuery      =      (D.ID = FCLookUp);

LCQuery   :  =      (B.ID= LCLookUp);


FilterQuery

IF      (FCLookUp<>0) & (LCLookUP<>0)

        FilterQuery = ( AreaQuery AND FCQuery AND LCQuery )

ELSE

        IF      FCLookUp <>0          FilterQuery       = ( AreaQuery AND FCQuery );

        IF      LCLookUp <>0          FilterQuery        = ( AreaQuery AND LCQuery );

        IF      (FCLookUp = 0) & (LCLookUp = 0)         FilterQuery = AreaQuery
```

- **Select Area**

function TSurvey.NewArea();

This method clears the input fields required for the area data, after which the default values are assigned to the various fields. *TSurvey.Area_Status* is assigned to *Insert*, to indicated the state of *TSurvey.Area*. This state is then used to build the query used to retrieve data from the database.

function TSurvey.SaveArea();

Dependant on *TSurvey.Area_Status*, a new record is entered into *TSurvey.Area*or a previous record is altered. After any of these actions, *TSurvey.Area* is updated and refreshed, displaying the new/altered record to the user.

function TSurvey.EditArea();

TSurvey.Area_Status is assigned to *Edit*, after which the data fields are populated with the values contained in *TSurvey.Area*. In addition to the area related functions, the query in Listing E-16 is also executed together with the query in Listing E-17. The result gained from Listing E-17 is assigned to *TSurvey.LoadEntries*, which is used to manage the data entries and is never shown to the user.

Listing E-17: Query to obtain all loads related to an area.

```
SELECT      *
FROM        LoadEntries
WHERE       AreaID = TSurvey.Area.DataSource.FieldByName('ID').AsInteger
```

After an area is selected, the user has three options:

- The area can be edited, after which the changes can be saved or discarded,
- The area can be deleted or
- A load can be added, edited or removed.

The first two options are limited to affiliates administrators while the third option can be executed by both the affiliate administrators and surveyors. The functions relating to the loads management are similar to those relating to the areas; however the queries executed vary and there is additional functionality incorporated, relating to the load and usage profile selection.

- **Select a Load**

function TSurvey.InsertLoad();

On adding a new load, *TSurvey.LoadEntries.Status* is set to *Insert*. After the functional class is selected, the load class options are set. After a load class is selected, the user is presented with the load options, as well as the options for the usage profiles. The load options and usage profiles are acquired by the queries presented in Listing E-18 and Listing E-19, respectively.

Listing E-18: Query to obtain the loads associated with a certain load class.

```
SELECT      ID, Designation
FROM        TSurvey.LoadClass_Details.FieldByName('TableRef').AsString
WHERE       Designation <> - ALL -
ORDER BY    ID ASC
```

Listing E-19: The query executed to determine the available usage profiles.

SELECT	B.ID, B.Designation
FROM	LC_UsageProfile_Link A
LEFT JOIN	UsageProfile B ON A.ProfileID=B.ID
WHERE	A.LoadClassesID = *TSurvey.LoadClass_Detail.DataSources.FieldByName('ID').AsInteger*
ORDER BY	B.ID ASC

After the user has selected the load and the various usage profiles, the user has the option to save or cancel.

function TSurvey.SaveLoad();

This function is operates in the exact same way as TSurvey.SaveArea(), with *TSurvey.AreaClientDataSet_Status* and *TSurvey.AreaDataSource* replaced by *TSurvey.LoadEntriesClientDataSet_Status* and *TSurvey.LoadEntriesSQLDataSet*, respectively. After the load is selected and the usage profile assigned *TSurvey.DisplayDataSource* is updated and refreshed, providing the user with the updates records.

function TSurvey.EditLoad();

The function is invoked on selecting a load, with *LoadEntries.Status* being set to *Edit*. The functional class is set together with the load class, which is done with the queries in Listing E-15 and Listing E-16, respectively. With the loads class set, the relevant load and usage profiles are selected, as contained in the database. All alteration can be saved of cancelled, depending on the user.

E.5.2 TUsageProfile

TUsageProfile, enables users to generate usage profiles form switching profiles by averaging them according to a time line and day specification provided by the user. In addition to the switching profile averaging, *TUsageProfile* can average temperature profiles according to a certain time line, also provided by the user. The window used is presented in Figure E-14 followed by the activity diagram in

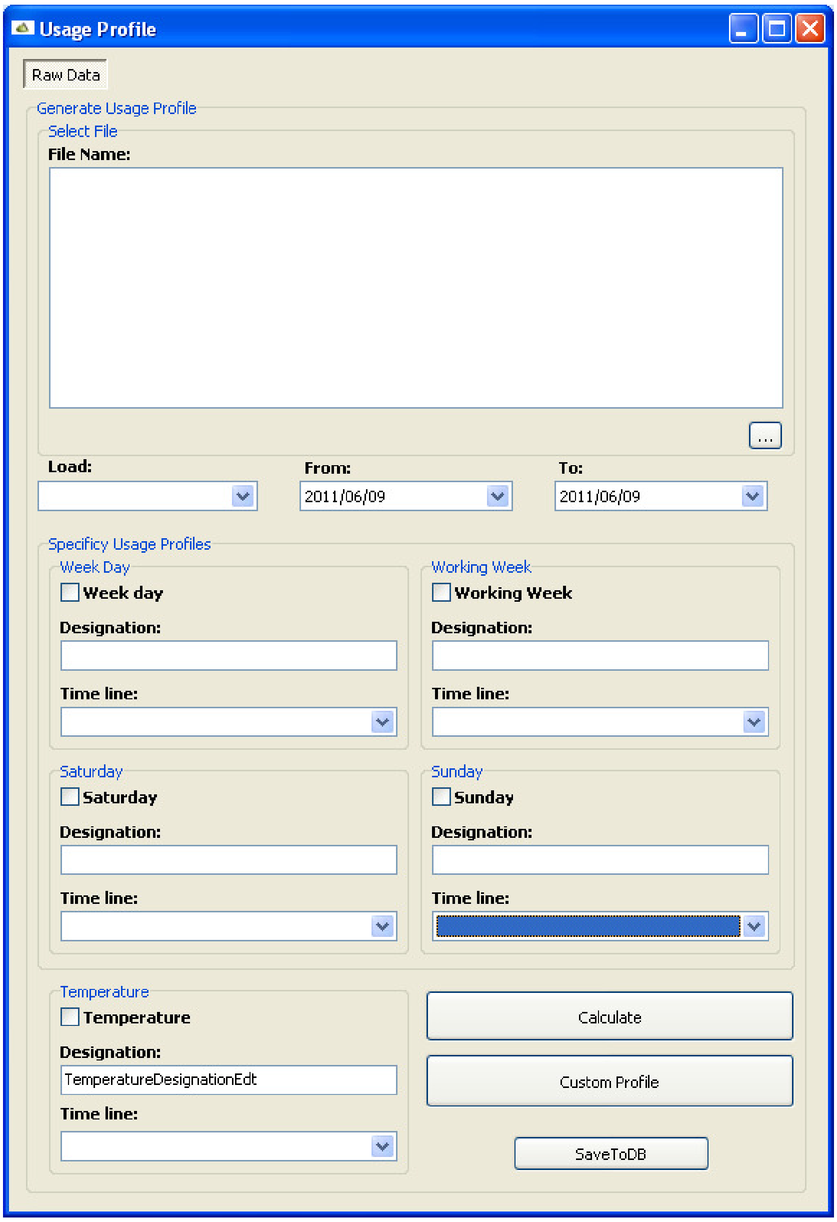


Figure E-14: Window used to generate usage profiles.

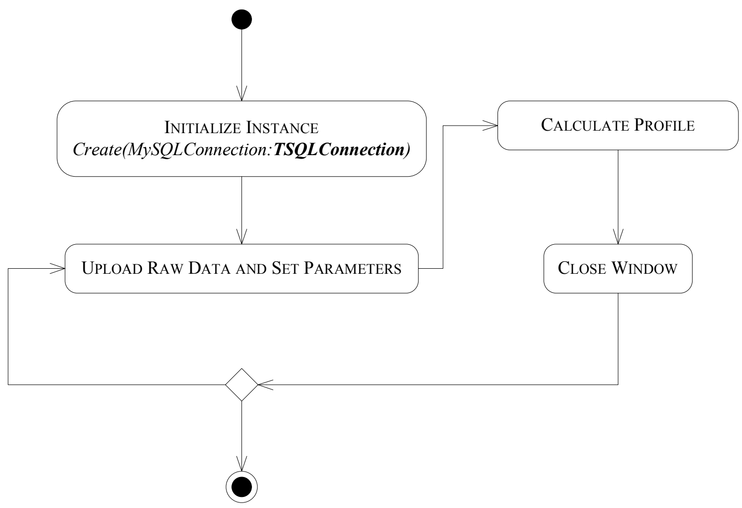


Figure E-15: Activity diagram for *TUsageProfile.*

TUsageProfile requires the averaging of a single or multiple switching profiles. Data handling is simplified by introducing four additional classes: *TFile*, *TTimeLineProfile*, *TTariff* and *TLoggerData*. The additional classes together with a short description of each is presented in *TLoggerData* is used to store the various switching profiles uploaded while *TTariff* groups all the completed time lines by making use of *TTimeLineProfile*.

After the instance has been initialized the user is required to upload either switching profiles or temperature profiles after which the averaging variables are set. With the files uploaded and the variables set, the profiles can be calculated.

- Initialize

constructor TUsageProfile.Create(*MySQLConnection;* ***TSQLConnection***);

When the class is initialized a series of queries are executed to provide the user with the load and time line options. The query in Listing E-20 is executed, the result is assigned to *TUsageProfile.Load* and presents the user with the loads to which usage profiles can be assigned.

Listing E-20: Load class query

SELECT	ID, Designation
FROM	*LoadClass*
WHERE	Designation <> - ALL -
ORDER BY	Designation

The various time line options is retrieved by executing the query in Listing E-21 and the result is assigned to *TUsageProfile.WeekDay*, *TUsageProfile.WorkingWeek*, *TUsageProfile.Sat* and *TUsageProfile.Sun,* the database components for the time lines of each day classification e.g. week days, working week, Saturday and Sunday, respectively. The result gained from Listing E-21 is also assigned to *TUsagePorfile.TemperatureDD*, enabling the user to specify the time line to which the temperature profile should be averaged.

Listing E-21: Time line query

SELECT	ID, Designation
FROM	*TimeLineInformation*
ORDER BY	Designation

- Upload Raw Data and Set Parameters

The user can upload multiple CSV-files containing switching or temperature data. After the upload has been completed the week day averaging specifications are set and the time line is assigned.

- Calculate Profile

The activity diagram presented in Figure E-16 illustrates the process followed to generate both the usage profiles and average the temperature profiles. A tariff for each of the uploaded files is created, after which the files are imported and processed. After the completion of the upload, the tariffs are averaged and saved to the database. The three stages of the calculation process are discussed in the remainder of this section.

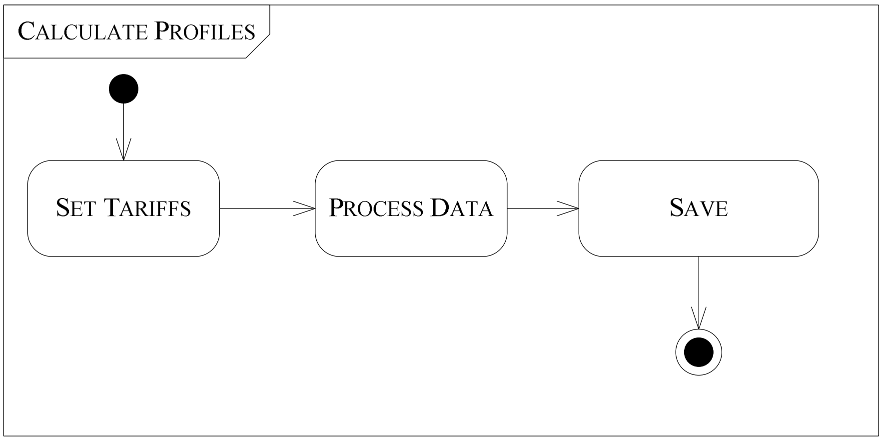


Figure E-16: The activity diagram for determining the profiles.

i. Set Tariffs

TUsageProfile.Tariffs is an array created with the same number of elements as the amount of files that were uploaded. *TUsageProfile.SummarisedTariff* contains only one element for it contains the final usage profiles, calculated from all the uploaded files.

After the *TUsageProfile.Tariffs* has been created, the time stamps for each element is set, based on the time line assigned by the user.

ii. Process Data

The data processing process repeats for each file uploaded and populates the elements contained in *TUsageProfiles.Tariffs*. The process followed is presented in **Error! Reference source not found.**.

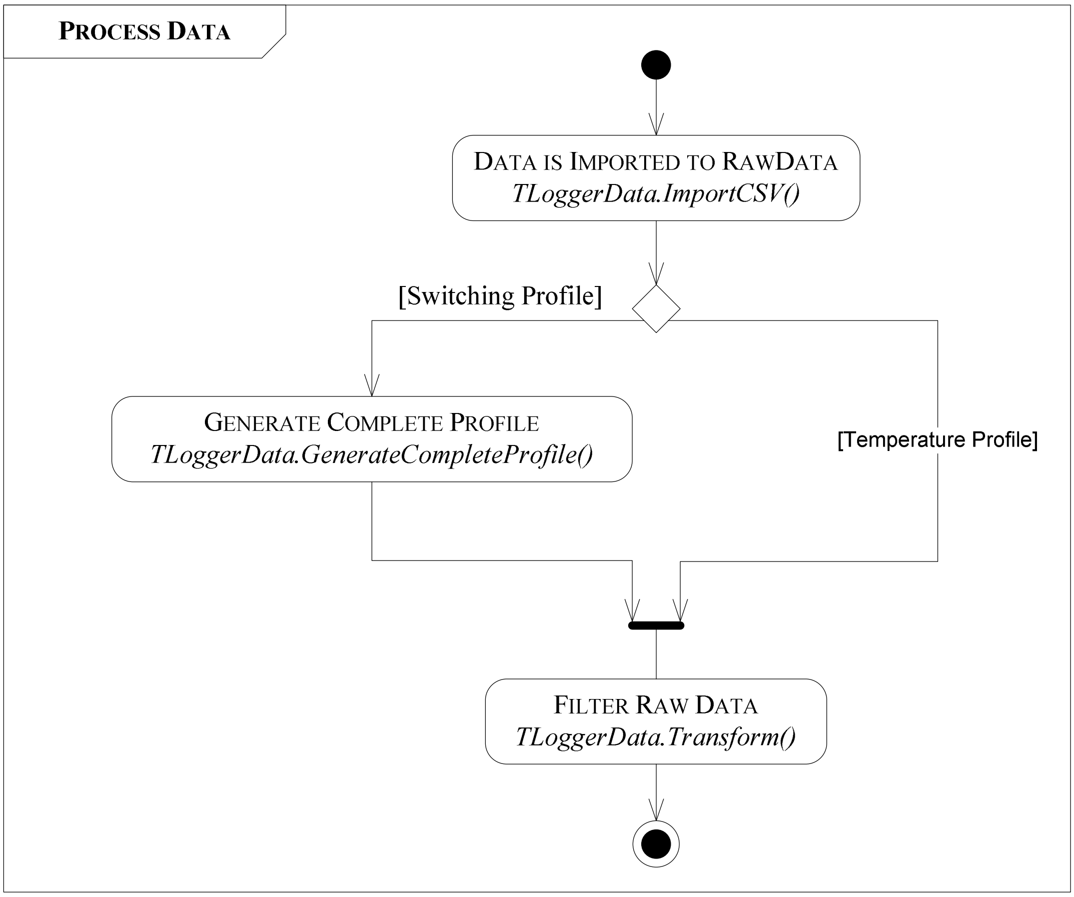


Figure E-17: The activity diagram for processing the uploaded files.

<u>**function** TUsageProfile.RawData.ImportCSV(*FilesToUpLoad:* ***String****; ProfileType:****String***)</u>;

TUsageProfile.RawData.ImportCSV() takes two parameters, the first being the file path of the file to be uploaded and the second is a string indicating the type of profile being uploaded. The function then assigns the data in the file to *TUsageProfile.RawData.RawData*, enabling the data to be accessed.

function TLoggerData. RawData.GenerateCompleteProfile();

TLoggerData. RawData.RawData is expanded and a 1 or a 0 is assigned to each minute between the first and the last time stamp, generating a complete profile.

function TLoggerData.RawData.Transformation(*From:**TDateTime**; To:**TDateTime**; Tariff:**TTariff***);

Averages a section of the complete profile according to the time line provided, where the section is determined by the *From* and *To* date specified by the users. The averaged profiles are then assigned to the associated element in *TUsageProfile.Tariffs*.

iii. Save

Before saving any profile, the average profile is determined. Depending on the type of profile, an averaging algorithm is applied after which a single profile is are saved to the database.

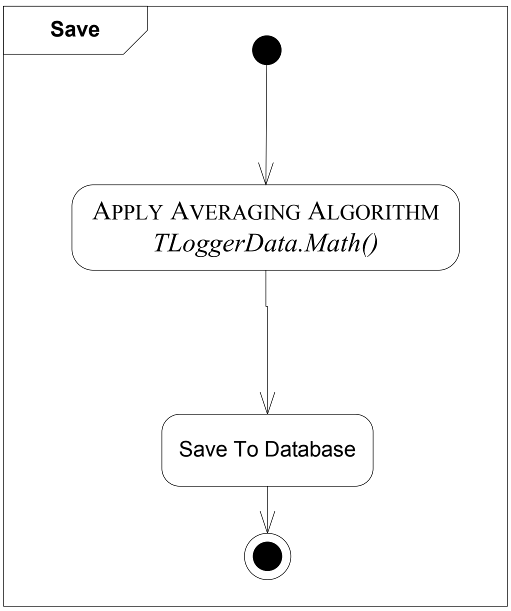


Figure E-18: The activity diagram for calculating the average profiles.

function TUsageProfile.Math();

A mathematical operation is applied to the elements in *TUsageProfile.Tariffs* resulting in a single set of profiles, which are assigned to *TUsageProfile.SummarisedTariff*. The set of profiles contained in *TUsageProfile.SummarisedTariff* is then saved to the database.

Appendix F COMPARATIVE TABLES

This appendix presents the tables containing the calculated values which were used to determine if the consumption profiles determined in section 6.2.3 were correct.

		00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Working Week	T_A	14.97	15.01	14.91	14.90	14.96	14.81	14.49	14.48	14.40	14.07	13.89	13.45	13.13	13.73	14.43	15.02	15.50	16.02	16.10	16.89	17.24	16.86	15.29	14.41	16.03
	D_A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.06	0.06	0.04
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.80	7.07	10.43	11.71	5.93

		12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Working Week	T_A	16.73	17.84	18.01	17.11	15.01	15.58	16.02	16.41	17.24	17.21	16.63	16.04	15.71	15.27	14.69	14.46	14.06	13.36	12.99	12.78	12.19	11.69	11.45
	D_A	0.03	0.03	0.01	0.01	0.06	0.08	0.06	0.06	0.06	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	4.17	3.37	1.40	1.03	11.55	13.02	9.38	9.69	7.61	9.19	3.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure F-1: The calculated values for each of the time values of the usage profile presented in Figure 6.4.

		00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Working Week	D_A	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.64	0.78	0.91	0.99	1.00	1.00	1.00	1.00	1.00	1.00
	E	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	26.95	31.36	38.22	44.59	48.51	49.00	49.00	49.00	49.00	49.00	49.00
Saturday	D_A	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.52	0.75	0.75	0.75	0.75	0.75	0.75
	E	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	25.48	36.75	36.75	36.75	36.75	36.75	36.75
Sunday	D_A	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.75	0.75	0.75	0.75	0.75
	E	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.99	36.75	36.75	36.75	36.75	36.75

		12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Working Week	D_A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.77	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.63	0.60	0.60	0.56
	E	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	47.04	37.73	34.30	34.30	34.30	34.30	34.30	34.30	34.30	34.30	34.30	30.87	29.40	29.40	27.44
Saturday	D_A	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.70	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	E	36.75	36.75	36.75	36.75	36.75	36.75	36.75	36.75	36.75	36.75	36.75	36.75	34.30	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50
Sunday	D_A	0.75	0.75	0.75	0.75	0.75	0.68	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	E	36.75	36.75	36.75	36.75	36.75	33.32	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50

Figure F-2: The calculated values for each of the time values of the usage profile presented in Figure 6.5, Figure 6.6 and Figure 6.7.

		00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Working Week	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.26	0.51	0.73	0.84	0.84	0.75	0.75	0.81	0.85	0.89
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.54	5.01	9.82	14.06	16.18	16.18	14.45	14.45	15.60	16.37	17.14
Saturday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunday	**D_A**	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	9.63	0.00	0.00	9.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

		12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Working Week	**D_A**	0.85	0.64	0.77	0.84	0.73	0.75	0.70	0.65	0.54	0.22	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	16.37	12.33	14.83	16.18	14.06	14.45	13.48	12.52	10.40	4.24	2.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saturday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.01	0.20	0.20	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.26	3.85	3.85	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure F-3: The calculated values for each of the time values of the usage profile presented in Figure 6.8 and Figure 6.9.

		00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Working Week	**D_A**	0.07	0.07	0.06	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.10	0.20	0.20	0.22	0.26	0.29	0.28	0.25	0.25
	E	0.41	0.41	0.35	0.18	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.59	1.17	1.17	1.29	1.52	1.70	1.64	1.46	1.46
Saturday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

		12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Working Week	**D_A**	0.24	0.22	0.20	0.23	0.24	0.24	0.24	0.22	0.11	0.09	0.05	0.05	0.02	0.02	0.04	0.07	0.08	0.10	0.08	0.07	0.07	0.07	0.07
	E	1.40	1.29	1.17	1.35	1.40	1.40	1.40	1.29	0.64	0.53	0.29	0.29	0.12	0.12	0.23	0.41	0.47	0.59	0.47	0.41	0.41	0.41	0.41
Saturday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.10	0.10	0.10	0.07	0.10	0.10	0.10	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.59	0.59	0.59	0.41	0.59	0.59	0.59	0.00
Sunday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.41	0.41	0.41	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure F-4: The calculated values for each of the time values of the usage profile presented in Figure 6.10, Figure 6.11 and Figure 6.12.

		00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Working Week	**D_A**	0.07	0.07	0.06	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.10	0.20	0.20	0.22	0.26	0.29	0.28	0.25	0.25
	E	2.80	2.80	2.40	1.20	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	4.00	8.00	8.00	8.80	10.40	11.60	11.20	10.00	10.00
Saturday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

		12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Working Week	**D_A**	0.24	0.22	0.20	0.23	0.24	0.24	0.24	0.22	0.11	0.09	0.05	0.05	0.02	0.02	0.04	0.07	0.08	0.10	0.08	0.07	0.07	0.07	0.07
	E	9.60	8.80	8.00	9.20	9.60	9.60	9.60	8.80	4.40	3.60	2.00	2.00	0.80	0.80	1.60	2.80	3.20	4.00	3.20	2.80	2.80	2.80	2.80
Saturday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.10	0.10	0.10	0.07	0.10	0.10	0.10	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	4.00	4.00	4.00	2.80	4.00	4.00	4.00	0.00
Sunday	**D_A**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80	2.80	2.80	2.80	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure F-5: The calculated values for each of the time values of the usage profile presented in Figure 6.103, Figure 6.114 and Figure 6.125.

Appendix G LOAD SURVEY

This appendix presents the floor plan of the third floor as well as the loads that were surveyed during the load survey.

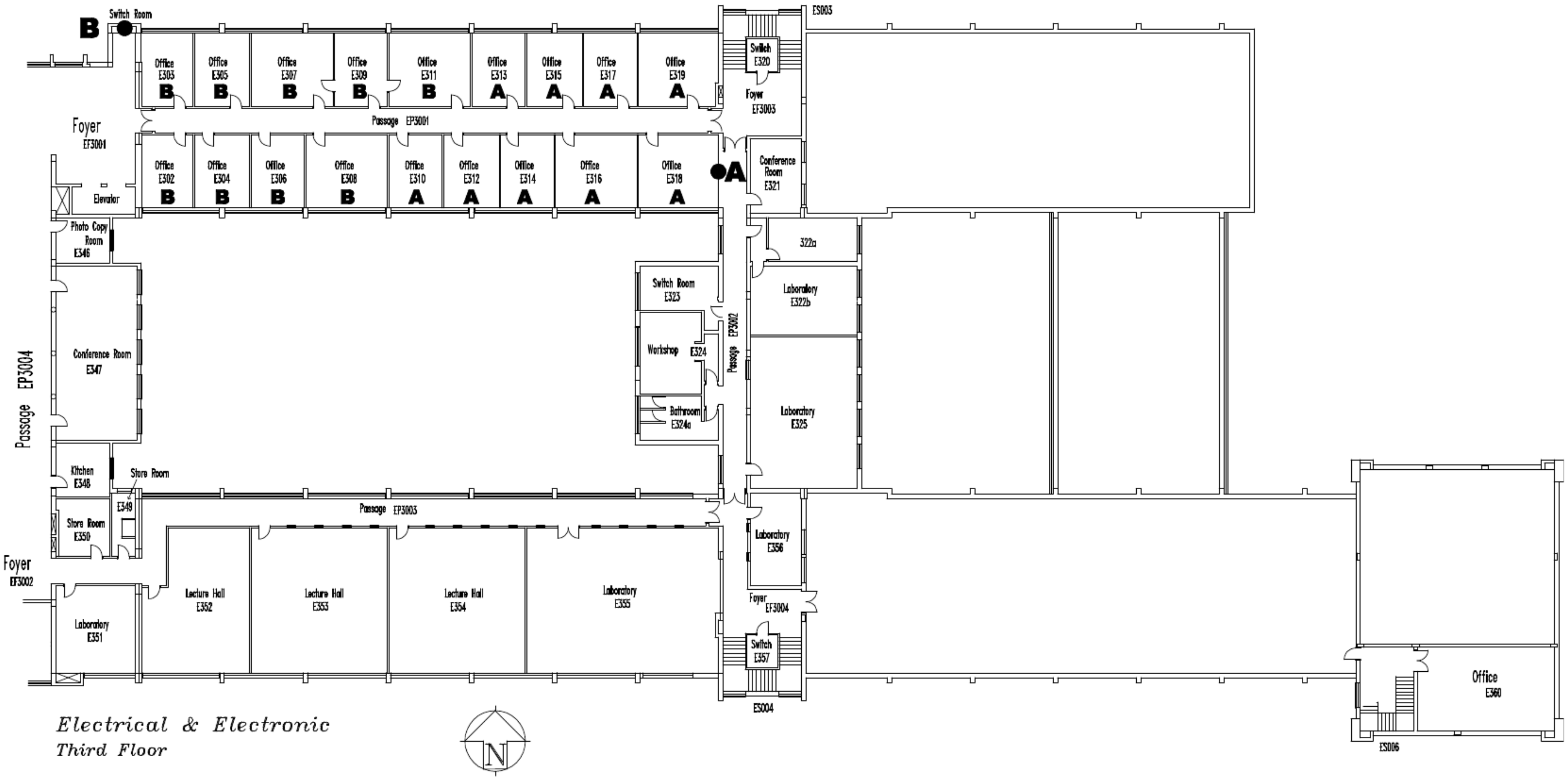


Figure G-1: Floor plan for the third floor of the Electrical and Electronic Engineering Faculty.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
302	Windows	Window A1			
302	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
302	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
302	Monitors	Monitor - 407318	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
302	Computers	Computer - 407318	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
303	Windows	Window A1			
303	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
303	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
303	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
303	Computers	Computer	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
303	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
304	Windows	Window A1			
304	Windows	Window A2			
304	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
304	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
304	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
304	Monitors	Monitor A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
304	Computers	Computer A1	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
304	Air Conditioners	Air conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
305	Windows	Window A1			
305	Windows	Window A2			
305	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
305	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
305	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
305	Monitors	Monitor A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
305	Computers	Computer	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
305	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
306	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
306	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
307	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
307	Windows	Window A1			
307	Windows	Window A2			

Figure G-2: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
307	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
307	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
307	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
307	Monitors	Monitor - 395481	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
307	Monitors	Monitor - 395481	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
307	Computers	Computer	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
308	Windows	Window A1			
308	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
308	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
308	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
308	Monitors	Monitor 1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
308	Monitors	Monitor 2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
308	Computers	Computer	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
308	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
309	Windows	Window A1			
309	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
309	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
309	Monitors	Monitor - 407797	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
309	Computers	Computer - 407797	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
309	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
310	Windows	Window A1			
310	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
310	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
310	Monitors	Monitor - 407803	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
310	Computers	Computer - 407803	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
310	Air Conditioners	Air Conditioner	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
311	Luminaires	Luminaires A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
311	Luminaires	Luminares A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
311	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
311	Air Conditioners	AC A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
311	Windows	Window A1			

Figure G-3: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
312	Windows	Window A1			
312	Windows	Window A2			
312	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
312	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
312	Monitors	Monitor - 422212	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
312	Computers	Computer - 422212	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
312	Computers	Computer - 403755	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
313	Windows	Window A1			
313	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
313	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
313	Monitors	Monitor - 421917	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
313	Monitors	Monitor - 421917	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
313	Computers	Computer - 421917	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
313	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
315	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
315	Luminaires	Luminare A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
315	Computers	Computer A1	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
315	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
315	Air Conditioners	AC A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
315	Windows	Window A1			
316B	Windows	Window A1			
316B	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
316B	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
316B	Monitors	Monitor A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
316B	Computers	Computer - 415512	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
316B	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
317	Windows	Window A1			
317	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
317	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
317	Monitors	Monitor	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
317	Computers	Computer - 408906	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min

Figure G-4: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
317	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
318C	Windows	Window A1			
318C	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
318C	Computers	Computer - 409271	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
318C	Monitors	Monitor - 409271	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
318C	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
319	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
319	Windows	Window A1			
319	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
319	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
319	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
319	Computers	Computer - Laptop	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
321	Computers	Computer - 400051	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
321	Computers	Computer - 400049	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
321	Computers	Computer A2	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
321	Windows	Window A1			
321	Windows	Window A1			
321	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
321	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
321	Monitors	Monitor - 400050	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
321	Computers	Computer - 400050	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
321	Monitors	Monitor - 395900	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
321	Computers	Computer - 395900	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
321	Computers	Computer A1	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
322A	Windows	Window A1			
322B	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
322B	Windows	Window A1			
322B	Windows	Window B1			
323	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
323	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324	Luminaires	Luminaire B3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min

Figure G-5: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
324	Luminaires	Luminaire C1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324	Luminaires	Luminaire C2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324	Computers	Computer - 371135	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
324	Luminaires	Luminaire C3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324	Windows	Window A1			
324	Lamps	Lamp A1	FINAL-lamps-ww-30 min	FINAL-lamps-sat-30 min	FINAL-lamps-sun-30 min
324	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324	Monitors	Monitor - 371135	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
324	Luminaires	Luminaire B2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
324A	Lamps	Lamp A1	FINAL-lamps-ww-30 min	FINAL-lamps-sat-30 min	FINAL-lamps-sun-30 min
347	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
347	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
347	Luminaires	Luminaire C1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
347	Luminaires	Luminaire D1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
348	Windows	Window A1			
351	Monitors	Monitor - 400015 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
351	Monitors	Monitor A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
351	Monitors	Monitor - 422422 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
351	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
351	Monitors	Monitor A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
351	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
351	Computers	Computer - 900015	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
351	Monitors	Monitor A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
351	Computers	Computer - 422422	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
351	Computers	Computer A1	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
351	Windows	Window A1			
355	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
355	Air Conditioners	Air Conditioner A2	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
355	Monitors	Monitor - 414355 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 414355 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min

Figure G-6: Surveyed loads

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
355	Computers	Computer - 414355	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Monitors	Monitor - 414356 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414356	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Monitors	Monitor - 414356 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414352	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414352 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414357	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414352 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414351	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414357 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414354	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414357 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414359	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A4	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414351 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400012	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A5	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414351 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400009	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A6	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414354 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 394149	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Computers	Computer - 400021	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire A7	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414354 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400017	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min

Figure G-7: Surveyed loads

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
355	Monitors	Monitor - 414359 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400010	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire B2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414359 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Luminaires	Luminaire B3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 400012	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Luminaires	Luminaire B4	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 400009	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 392890	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire B5	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 394149	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400016	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire B6	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 400021	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 398538	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire B7	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 400010	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414353	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 292890	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400014	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 400016	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414360	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 398538	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414361	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C4	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 414393 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 400019	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C5	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min

Figure G-8: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
355	Monitors	Monitor - 414393 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 400041 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 414358	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C6	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Monitors	Monitor - 400014 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Computers	Computer - 394204	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Luminaires	Luminaire C7	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
355	Computers	Computer - 383120	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Computers	Computer - 394206	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
355	Monitors	Monitor - 414360	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 414361 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 414361 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 400019	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 414358 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 414358 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 394204 - A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 394204 - A2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 383120	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Monitors	Monitor - 394206	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
355	Windows	Window A1			
355	Windows	Window A2			
355	Windows	Window A3			
356	Computers	Computer A1	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
356	Monitors	Monitor A1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Air Conditioners	Air Conditioner A1	FINAL - AC - Nov - ww	FINAL - AC - Nov - sat	FINAL - AC - Nov - sun
360	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
360	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
360	Computers	Computer - 408710	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
360	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
360	Computers	Computer - 396994	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
360	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min

Figure G-9: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
360	Computers	Computer	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
360	Luminaires	Luminaire B2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
360	Computers	Computer - 408709	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
360	Luminaires	Luminaire B3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
360	Computers	Computer_2	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
360	Computers	Computer - Personal	FINAL-computer-ww-30 min	FINAL-computer-sat-30 min	FINAL-computer-sun-30 min
360	Monitors	Monitor 408710	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Monitors	Monitor 396994	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Monitors	Monitor - SBN803 [A1] 660	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Windows	Window A1			
360	Monitors	Monitor - 408709	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Monitors	Monitor 1	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Monitors	Monitor 2	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
360	Monitors	Monitor 3	FINAL-monitors-ww-30 min	FINAL-monitors-sat-30 min	FINAL-monitors-sun-30 min
F3001	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
F3001	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
F3001	Luminaires	Luminaire C1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
F3003	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
F3004	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
F3004	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
F3004	Luminaires	Luminaire C1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A4	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A5	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A6	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A7	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3001	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3002	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3002	Luminaires	Luminaire B1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3002	Luminaires	Luminaire C1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min

Figure G-10: Surveyed loads.

Area	Load Class	Load Designation	Working Week Profile	Saturday Profile	Sunday Profile
P3002	Luminaires	Luminaire D1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3002	Luminaires	Luminaire E1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3002	Windows	Window A1			
P3002	Luminaires	Luminaire F1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3002	Windows	Window B1			
P3002	Lamps	Lamp A1	FINAL-lamps-ww-30 min	FINAL-lamps-sat-30 min	FINAL-lamps-sun-30 min
P3003	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Windows	Window A1			
P3003	Luminaires	Luminaire A1	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Windows	Window A2			
P3003	Luminaires	Luminaire A2	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Windows	Window A3			
P3003	Luminaires	Luminaire A3	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Windows	Window A4			
P3003	Luminaires	Luminaire A4	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Windows	Window A5			
P3003	Windows	Window A6			
P3003	Luminaires	Luminaire A6	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Windows	Window A7			
P3003	Luminaires	Luminaire A7	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Luminaires	Luminaire A8	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min
P3003	Luminaires	Luminaire A9	FINAL-luminaires-ww-30 min	FINAL-luminaires-sat-30 min	FINAL-luminaires-sun-30 min

Figure G-11: Surveyed loads.